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High Energy Missile: A comparative study

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Defence R&D Canada – Valcartier
Technical Memorandum
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Abstract

This study uses a simple spreadsheet model to simulate a one-on-one engagement between two combat vehicles with the objective of comparing the performance of the High Energy Missile (HEMi) mounted on a Light Armoured Vehicle (LAV3) with that of the LAV TOW Under Armour (LAV TUA), the Mobile Gun System, and the 25 mm APFSDS on a LAV3. These BLUE systems were placed in conflict with a variety of RED threats, both guided and unguided.

The results suggest that in long-range engagements or in engagements with a T-80U at any range, the LAV3 carrying the HEMi is the superior system. Both the MGS and the LAV3 with a 25 mm APFSDS are better suited to shorter-range engagements against a BMP2.

Résumé

Dans la présente étude, un modèle simple de chiffrier électronique a été utilisé pour simuler un engagement un-contre-un entre deux véhicules avec pour objectif de comparer la performance du missile à haute énergie (HEMi) monté sur véhicule blindé léger (VBL III) à celles du VBL TSB (TOW sous blindage), du système de canon mobile (Mobile Gun System – MGS) et du canon de 25 mm avec projectile de type fléchette monté sur VBL III. Ces systèmes BLEU ont été placés en conflit avec diverses menaces ROUGE, tant guidées que non-guidées.

Les résultats semblent indiquer que, dans les engagements à longue portée et dans tous les engagements contre le T-80U, indépendamment de la portée, le VBL III armé du système HEMi est supérieur. Le système de canon mobile et le VBL III armé du canon de 25 mm avec projectile de type fléchette sont mieux adaptés pour les engagements à courte portée contre le BMP2.

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Executive summary

The purpose of this study was to compare the performance of a High Energy Missile (HEMi) mounted on a Light Armoured Vehicle 3 (LAV3) with that of the LAV TOW Under Armour (LAV TUA), the Mobile Gun System, and the 25 mm APFSDS on a LAV3. The scope was very limited: a series of one-on-one engagements between these BLUE systems and a variety of RED systems (BMP2 with 30 mm APDS-T, BMP2 with AT-5, T-80U with 125 mm APFSDS, and T-80U with AT-11) were simulated using a simple spreadsheet model.

The spreadsheet model considered the following factors for both the BLUE and RED systems to determine the outcome of the engagement: the time to detect and recognize the enemy, the lay and aim times of the weapon, the time of flight of the round, the probability of hit, and the probability of kill given a hit. Numerous iterations were performed for each BLUE-RED pairing to determine the probability of a BLUE kill and the probability of a BLUE loss.

It is important to be aware of the limitations of the approach used in this study. Several simplifying assumptions were made, and some factors that could impact the outcome of the engagement were not considered. Because of these limitations, the results should be interpreted with caution. They should not be regarded with the same credibility that one might accord the results of a war game. Even so, some general conclusions can be drawn, provided that the reader is well aware of the underlying assumptions of the study.

Of the BLUE systems considered, the LAV3 carrying the HEMi is the only one that has sufficient range to engage targets beyond 3.75 km. The results also suggest that this system is superior to the others when used against a T-80U. This is due to its ability to defeat the T-80's armour in a timely manner. However, the MGS and the LAV3 carrying a 25 mm APFSDS appear to be more effective against a BMP2 at short range.

An optimum solution might be to mount both the 25 mm APFSDS and the HEMi on a LAV3. In that case, the 25 mm gun could be used against softer targets (such as the BMP2) at short range, while the HEMi could be reserved for harder targets as well as any long-range targets.

Straver, M.C., Fournier, P. 2005. High Energy Missile: A Comparative Study. DRDC Valcartier TM 2005-292. DRDC Valcartier.

Sommaire

L'objectif de la présente étude était de comparer la performance du missile à haute énergie (HEMi) monté sur véhicule blindé léger (VBL III) à celles du VBL TSB (TOW sous blindage), du système de canon mobile (Mobile Gun System – MGS) et du canon de 25 mm APFSDS monté sur VBL III. La portée de l'étude était très limitée : une série d'engagements un-contre-un entre les systèmes BLEU et divers systèmes ROUGE (un BMP2 armé d'un canon 30 mm APDS-T, un BMP2 armé d'AT-5, un T-80U armé du canon de 125 mm APFSDS et un T-80U tirant un missile AT-11) a été simulée au moyen d'un modèle simple de chiffrier électronique.

Les facteurs suivants ont été pris en considération dans le modèle de chiffrier, tant pour les systèmes BLEU que pour les systèmes ROUGE, afin de déterminer le résultat des engagements : temps requis pour détecter et reconnaître l'ennemi, temps requis pour pointer et viser l'arme, durée de vol du/des projectiles, probabilité de coup au but et probabilité de destruction en cas de coup au but. Plusieurs répétitions ont été effectuées pour chaque paire BLEU-ROUGE afin de déterminer les probabilités de destruction et de perte BLEU.

Il est important de tenir compte des restrictions de l'approche utilisée dans cette étude. Plusieurs hypothèses ont été faites, et certains facteurs pouvant influer sur le résultat des engagements n'ont pas été pris en considération. Compte tenu de ces restrictions, les résultats doivent donc être interprétés avec prudence. On ne doit pas leur donner le même crédit que les résultats pouvant être obtenus lors de jeux de guerre. Il n'empêche que certaines conclusions générales peuvent être tirées en autant que le lecteur reste bien conscient des postulats présents dans l'étude.

Dans le cas des systèmes BLEU étudiés, seul le VBL III armé du HEMi jouit d'une portée suffisante pour engager des objectifs au delà de 3,75 km. Les résultats semblent également indiquer que ce système est supérieur aux autres lorsqu'il est utilisé contre le T-80U. Cela est dû à sa capacité de percer le blindage du T-80 dans un délai suffisamment court. Cependant, le système de canon mobile et le VBL III armé du 25 mm APFSDS semblent être plus efficaces lorsque vient le temps d'engager un BMP2 à courte portée.

Une solution optimale pourrait donc être d'installer à la fois le 25 mm et le HEMi sur le VBL III. Le canon de 25 mm pourrait ainsi être utilisé contre des objectifs légers (tels que le BMP2) à courte portée, alors que le HEMi pourrait être réservé pour engager les objectifs lourds de même que tous objectifs à longue portée.

Straver, M.C., Fournier, P. 2005. High Energy Missile: A Comparative Study. DRDC Valcartier 2005-292. DRDC Valcartier.

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Acknowledgements

The authors acknowledge the important contribution of Mr. Richard Lestage, who provided the data on weapon performance.

1. Introduction

1.1 High Energy Missile

The aim of the HEMi TDP is to demonstrate the concept of a small hypervelocity missile that would provide the firepower of a main battle tank (MBT) in a Light Armoured Vehicle (LAV) [1]. The HEMi is depicted in Figure 1. It is approximately 1.2 m in length and has a mass of approximately 22 kg. The development of the missile draws from several areas of technological expertise at Defence Research & Development Canada (DRDC) – Valcartier to optimize the lethality, propulsion system, guidance and control, aerodynamics, and launch mechanism. At the time of writing, DRDC Valcartier was developing a mock-up of the missile with all of its functionality. A prototype of the missile may be built in the future.

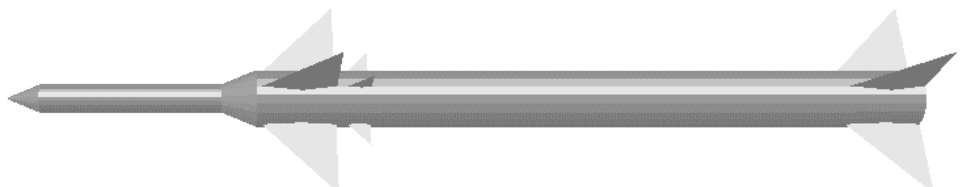

Figure 1. *The HEMi*

1.2 Previous OR work

One previous OR study on the HEMi attempted to estimate the impact that the HEMi would have in a typical combat scenario. The study found that because of its long range and powerful penetration capability, the HEMi has the potential to be an excellent replacement for the 105 mm APFSDS in that it could increase the total number of kills and the ranges at which those kills occur. However, the study had many limitations, the most significant being that it did not capture the impact that the HEMi would have on the dynamics of the battle [2].

1.3 Objective

The objective of this study was to compare the performance of a LAV-mounted HEMi with that of the LAV TOW Under Armour (LAV TUA), the Mobile Gun System (MGS), and a LAV-mounted 25 mm APFSDS in one-on-one engagements against a variety of modern threats, both guided and unguided.

Like the first study on the HEMi, this study has many limitations. It is not an extension of the previous study, but rather looks at the problem from a different perspective to provide additional insights that were not gained from the earlier work.

2. Analysis method

The analysis consisted of Monte Carlo simulations that were performed using an Excel spreadsheet coupled with @Risk software to facilitate a large number of iterations. Ten thousand iterations were done for each case. Although this number seems excessively high, it was in fact not high enough to reach convergence in some cases. It was not increased further because doing so would increase the computing resources required without much payoff in the form of "better" results.

To keep the number of variants to a reasonable level, the analysis was done for only two scenarios for each BLUE-RED pairing: one in which RED was the attacker (defensive), and the other in which BLUE was the attacker (offensive). In the defensive scenario, the RED vehicle was moving and exposed (but stopped to shoot) while the BLUE vehicle was stationary and in partial defilade. In the offensive scenario, these postures were reversed. It was also assumed that BLUE would always present its flank to RED, and RED would present itself head-on to BLUE. This was chosen to make the scenarios more challenging for BLUE.

Each iteration of each simulation considered the time to detect and subsequently recognize the enemy vehicle, the lay and aim times of each weapon, the time of flight of each weapon, the probability of hit (P_{hit}), and the probability of kill given a hit ($P_{kill/hit}$) to determine the outcome for that iteration.

For each scenario, the BLUE systems were then compared to each other in terms of the number of kills and the number of losses.

2.1 Weapon systems

The simulations were performed for the HEMi mounted on a LAV3, the LAV TUA (a TOW2B mounted on a LAV3), and the MGS (in this study, a 105 mm APFSDS mounted on a Stryker-like chassis, although the MGS can accommodate different types of munitions). The 25 mm APFSDS was also included in the analysis because it had been proposed that it could be mounted on a LAV3 along with the HEMi, to be used at shorter ranges and/or against smaller targets. The LAV3 is shown in Figure 2, and the MGS is shown in Figure 3.

Figure 2. *The LAV 3 [3]*

Figure 3. *The MGS [3]*

The opposing RED systems included the BMP2 carrying either a 30 mm APDS-T or an AT-5 Spandrel, and the T-80U carrying either a 125 mm APFSDS or an AT-11 Sniper. Figure 4 shows the BMP2 and Figure 5 shows the T-80U.

Figure 4. *The BMP2 [4]*

Figure 5. *The T-80U [4]*

The characteristics of each system are shown in Table 1. Table 1 also indicates an abbreviated name for each system that will be used for simplicity throughout this report. The lay and aim times are approximations, and each value for the weapon speed was taken as the speed at a distance halfway to that weapon's maximum range. P_{hit} and $P_{kill/hit}$ data are shown in Annex A for each BLUE-RED pairing. Note that the LAV3/25 was not paired with the T-80U because a LAV3 would never attempt to fire a 25 mm round at a tank due to the extremely low probability of kill.

All data were obtained from the Janus database (Canadian version) [5], with the exception of the data pertaining to the HEMi, as this weapon does not exist in the database. An estimate of the speed and maximum range were provided by a scientist involved with the HEMi project [6]. The lay time was taken to be the same as that for the 105 mm APFSDS, and the aim time was taken to be the same as for the AT-11,

which, like the HEMi, is a laser beam rider. The P_{hit} and $P_{kill/hit}$ data were also based on the data for the AT-11, as the capabilities are expected to be similar in terms of weapon guidance and penetration.

Table 1. *Characteristics of weapon systems*

ABBREVIATED NAME	WEAPON	VEHICLE	LAY TIME (s)	AIM TIME (s)	SPEED (km/s)**	RANGE (km)
LAV3/HEMi	HEMi	LAV3	4*	1*	2.30	5
LAV TUA	TOW 2B	LAV3	3	4	0.30	3.75
MGS	105mm APFSDS	Stryker (equivalent)	4	4	1.41	3
LAV3/25	25mm APFSDS	LAV3	4	3	1.24	2.2
BMP2/30	30 mm APDS-T+	BMP2	7	5	1.03	1.5
BMP2/AT5	AT-5	BMP2	6	10	0.27	4
T80U/125	125 mm APFSDS	T-80U	4	5	1.72	2.5
T80U/AT11	AT-11	T-80U	4	1	0.39	5

* estimate (actual value unknown)

** speed at mid-range

+ three shots fired at once

2.2 Assumptions, limitations, and points to consider

Two major simplifying assumptions were made with respect to the target acquisition process. First, each simulation began with both vehicles in each other's field of view (FOV) and with a clear line of sight between the two. Although in reality it is not often that two vehicles would enter into each other's FOV at precisely the same moment, this assumption was considered acceptable because it does not favour one side over the other.

Second, only one sensor was used on each vehicle. The same sensor (a modern Forward-Looking Infra-Red (FLIR)) was used for all BLUE systems to ensure that no one system had an advantage over another because of its sensing capabilities. A vehicle would in reality be equipped with more than one sensor. These sensors could be looking in different directions at different times, and any one of them could make the initial detection of a target.

The detection/recognition algorithm used by Janus was implemented in the spreadsheet model. It considers the following factors: the range to the target, the target's aspect and characteristic dimension, the proportion of the target that is visible, the movement of the observer and of the target, and the thermal contrast between the target and the background. This algorithm is outlined in Reference 7.

It was assumed that the sensor would initially be operated using a Wide Field of View (WFOV) until a detection was made, and then it would be switched to a Narrow Field of View (NFOV) to make a recognition. A two-second time delay was incorporated to account for the time required to switch the magnification. Once a vehicle recognized its enemy, it had permission to fire.

Of the weapons considered in this study, the TOW2B and the AT-5 cannot be fired on the move. P_{hit} is much lower when the firer is moving as compared to when it is stationary. It was initially thought that this disadvantage might be offset by the fact that a moving vehicle is less vulnerable to enemy fire (although it would be more easily detected). However, some preliminary results showed that in the context of this analysis, any system that stopped to shoot had an unfair advantage over a system that fired on the move. Therefore, to ensure a fair comparison between all weapons, it was decided that all vehicles would stop to shoot. For the defensive scenarios, it was assumed that RED would move until it recognized BLUE, and then stop to shoot. The appropriate P_{hit} value for BLUE was selected based on whether or not RED was moving at the time of fire. The reverse was true for the offensive scenarios. It should be noted that in an actual scenario, there could be reasons why one would wish to keep moving while firing, even considering the reduction in P_{hit}.

It was assumed that the operator of a weapon would become distracted and incapable of completing his/her task if his/her vehicle was hit, regardless of whether or not the vehicle was killed. This assumption led to the following further assumptions:

- a weapon will not be fired if its host vehicle is hit first;
- a guided missile will miss its target if its host vehicle is hit; and
- if a vehicle is hit after firing an unguided round, the round may still hit its target.

The first of these is highly questionable. However, this situation occurred infrequently in nearly all scenarios, and therefore could not have made a significant impact on the results in those cases. In the scenarios in which it did occur frequently, namely the cases in which the MGS fired against a T-80U, it did not preclude some conclusions from being drawn. This will be discussed in more detail in Section 3 for the applicable cases.

As a consequence of the three aforementioned assumptions, the outcome of the engagement was dependent on the sequence of the four events (BLUE fires, BLUE impacts, RED fires, and RED impacts) and on the stochastic $P_{hit}/P_{kill/hit}$ results (one of either BLUE kills, BLUE hits but does not kill, or BLUE misses; and one of either RED kills, RED hits but does not kill, or RED misses). There was a total of 54 possible sequence/result combinations, each of whose outcome was dependent on whether the weapons being fired were guided or not. A lookup table, shown in Annex B, was used to determine the outcome of the engagement. The possible outcomes were:

- BLUE alive, RED dead;

- BLUE dead, RED alive;
- BLUE and RED dead; and
- BLUE and RED alive.

In the model created for this study, each system fired only once. In reality, for unguided weapons, a system would likely fire several times to increase the probability of killing the enemy. For guided missiles, a vehicle would likely fire a second shot after learning that the first shot was not effective. This was not accounted for because it was decided that the small increase in accuracy of the model did not merit the considerable increase in complexity that would have been required.

As a related point, the BMP2/30 fires three rounds with each trigger pull. This was accounted for in the model. The P_{hit} and $P_{kill/hit}$ values shown in Annex A were used to evaluate each round independently. Thus, a miss for the first round, for example, had no impact on whether or not the second and third rounds hit the target.

An additional limitation of the study concerns the reliability of the input data. As stated previously, all data were taken from the Janus database. Although the P_{hit} data are generally considered reliable, their accuracy cannot be confirmed. The data for $P_{kill/hit}$ are even more problematic. Multiple kill categories (mobility, firepower, and catastrophic) were not considered. Furthermore, for most weapons, the value of $P_{kill/hit}$ was 95% for all ranges and targets, which is clearly questionable. More reliable data were not available at the time this study was done.

It is important to understand the strong sensitivity of the results on the lay and aim times that were used in the model. To illustrate with an example, in the offensive scenario against the T80U/AT11, the LAV3/HEMi performs much better than the LAV TUA despite the fact that their P_{hit} and $P_{kill/hit}$ values are equal. At longer ranges, this can be attributed in part to the HEMi's higher flight speed; however, at shorter ranges, the major contributing factor is the shorter aim time of the HEMi. The difference between the sum of the lay and aim times is only two seconds, but this difference leads to a quite dramatic difference in the outcome of the series of engagements. The reader should be aware that the lay and aim times represent average durations, and could vary widely in different situations. This is especially true for the lay time.

This study is by no means intended to achieve the same goals as a war game. It is meant to provide insights into how the BLUE *weapons* compare, not into how the overall BLUE *systems* compare. It is important to note that overall system performance is dependent on the collective performance of various subsystems including the sensors and fire control system, in addition to the weapon itself. Additional factors such as interactions between vehicles on the same force, tactics, techniques, and procedures (TTPs), and human factors are also important, yet could not be considered in this study. When interpreting the results, the reader must keep in mind the assumptions and limitations that were stated in this section.

It is also important to be aware that the results obtained in this study are not transferable to other scenarios. This study considered one-on-one engagements between two similarly-equipped forces on open terrain. In current operations, however, it is increasingly likely that a conflict would occur against an asymmetric threat in an urban area. Although the HEMi could possibly perform as well as other weapons in such a situation, its powerful penetration capability and long range could not be exploited – thus, one could argue that using such a weapon would be a waste of resources. One could also argue, however, that having HEMi-equipped vehicles would project an image of a powerful force, which could have favourable psychological effects on the enemy.

3. Results and Discussion

In the remainder this document, the terms "probability of kill" and "probability of loss" refer to the results of the analysis. "Probability of kill" should not be confused with "$P_{kill/hit}$", which is the probability of kill given a hit for a particular weapon used against a particular target.

The probability of kill and the probability of loss in each scenario are interrelated. If the probability of kill increases, the probability of loss will tend to decrease because a killed enemy is unable to return fire. As the range increases, a number of factors will complicate the patterns of kills and losses. Factors that tend to decrease the probability of BLUE kill (and consequently increase the probability of BLUE loss) as the range increases include greater difficulty in recognizing the enemy and a reduction in the P_{hit} of the BLUE weapon. Similarly, other factors tend to decrease the probability of BLUE loss. These include a reduction in the enemy's ability to recognize the BLUE vehicle and a reduction in the enemy's P_{hit}. Additionally, the kills and losses are influenced by the weapons' lay and aim times. If a system requires a relatively long time to prepare to fire, the enemy will have greater opportunity to shoot. All of these factors interplay such that the end results shown in the graphs presented in this section may appear odd at first glance. For example, the probability of loss may first increase as the range increases, and then decrease. The reader should keep this in mind while reading the following sections, which will look at each RED system and summarize the comparative performance of the BLUE systems.

Although the trends in the probabilities of kill and loss follow similar patterns for both the defensive and offensive scenarios in many cases, the probability of kill is lower and the probability of loss is higher in the offensive scenarios. This is due to the more vulnerable posture of the BLUE system. Since BLUE is moving (until it recognizes the enemy and stops to shoot) and exposed while RED is stationary and in partial defilade, it is relatively difficult for BLUE to recognize RED, and easy for RED to recognize BLUE. Furthermore, after a recognition has been made and a shot fired, it is difficult for BLUE to hit RED, and easier for RED to hit BLUE. This is true for all scenarios considered in this study.

Figure 6 through Figure 21 show the probability of kill and the probability of loss for each case that was studied. The Loss Exchange Ratio (LER) is shown in Annex C. The LER is determined by dividing the number of BLUE kills by the number of BLUE losses for each case. Although the LER is often a useful way of comparing results, it can be misleading in cases where the number of kills or losses is very low. This occurred for some cases in this study. For example, consider the MGS and the LAV3/25 against the BMP2/30 at a range of 0.5 km, shown in Figure C1. The MGS kills 9493 enemies and suffers one loss, resulting in an LER of 9493. The LAV3/25 kills 9508 enemies and suffers two losses, with an LER of 4754. Clearly the two systems are comparable within the context of this analysis, but looking at the LER alone would suggest that the MGS is approximately two times as effective as the LAV3/25 for that case. For this reason it is recommended that the reader focus on the

probabilities of kill and loss rather than on the LER. Also included in Annex C are the probabilities of a shot being fired by the BLUE and the RED vehicles. Annex D contains the tabulated data for the LER, the probability of BLUE kill, the probability of BLUE loss, the probability of BLUE shot fired, and the probability of RED shot fired.

3.1 BMP2 with 30mm APDS-T

As shown in Figure 6 through Figure 9, at a range of 500 m (and to a lesser extent, at 1 km), the LAV3/25 and the MGS outperform the LAV3/HEMi and the LAV TUA in terms of both the probability of kill and the probability of loss in both scenarios. This can be attributed to their high P_{hit} values.

As the range increases, the probability of kill decreases for all BLUE systems because of the increased difficulty in recognizing the target. The systems that use an unguided weapon also suffer from a considerable reduction in P_{hit}. This drop in the probability of kill tends to increase the probability of loss, but it is partially balanced by the equivalent factors working against the RED system.

No BLUE systems suffer any losses beyond the 30 mm APDS-T's maximum range of 1.5 km. At this range, all BLUE systems perform fairly comparably. Beyond this point, the LAV3/HEMi has the highest probability of kill, followed by the LAV TUA, the MGS, and the LAV3/25. This result is directly related to the P_{hit} of the weapons. The lay time, aim time, and time of flight of the BLUE weapons do not affect the probability of kill when the RED target is unable to fire.

Beyond its maximum range of 2.2 km, the 25mm APFSDS is ineffective, while the HEMi and the TOW continue to outperform the MGS's 105 mm APFSDS. The HEMi is the only weapon that can be used at ranges over 3.75 km. However, in the offensive scenario, even the HEMi does not kill any enemy systems at longer ranges because of the difficulty in recognizing the target.

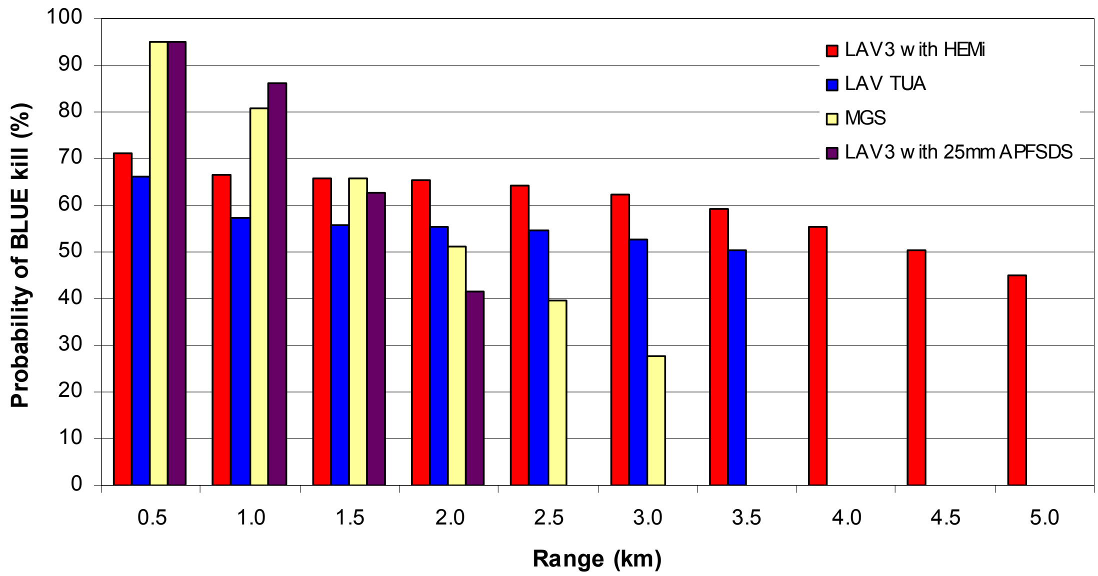

Figure 6. *BMP2 with 30 mm APDS-T, defensive scenario: probability of BLUE kill*

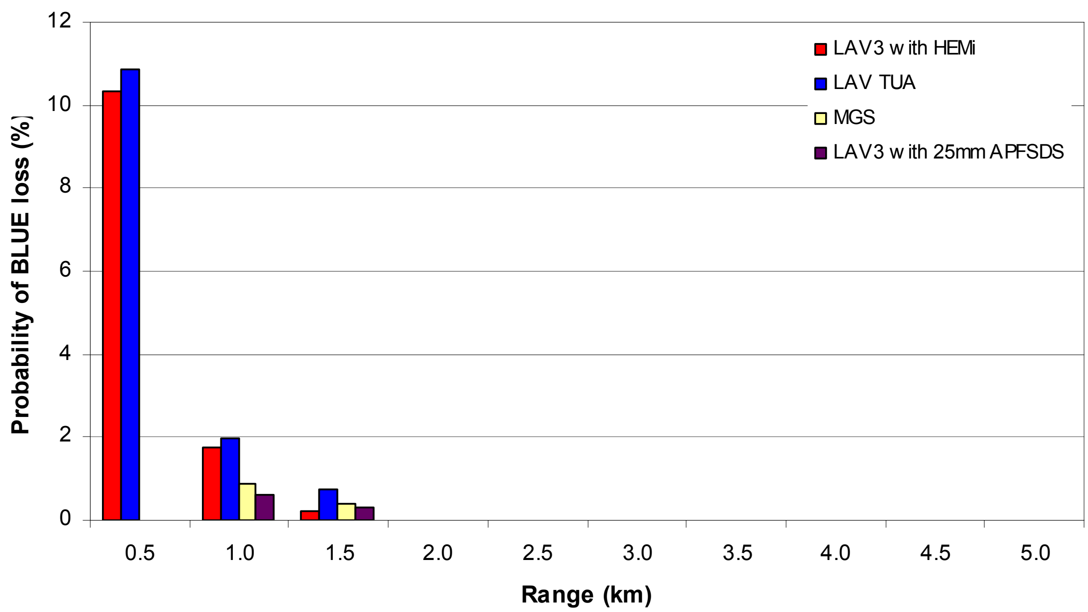

Figure 7. *BMP2 with 30 mm APDS-T, defensive scenario: probability of BLUE loss*

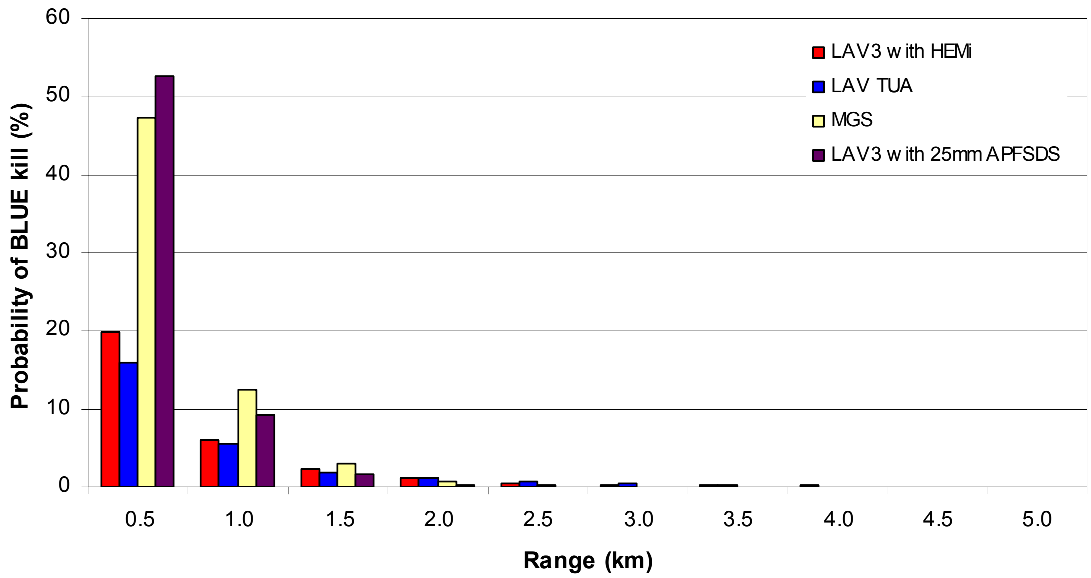

Figure 8. *BMP2 with 30 mm APDS-T, offensive scenario: probability of BLUE kill*

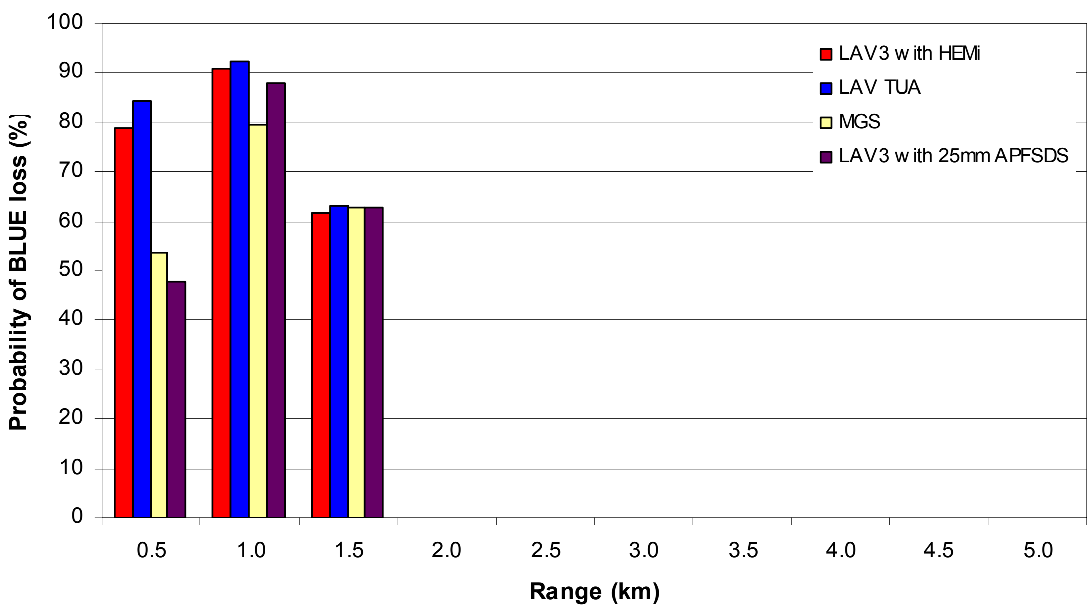

Figure 9. *BMP2 with 30 mm APDS-T, offensive scenario: probability of BLUE loss*

3.2 BMP2 with AT-5

Figure 10 through Figure 13 show the results for the BLUE systems versus the BMP2/AT5. As in the previous case, the MGS and the LAV3/25 perform better than

the LAV3/HEMi or LAV TUA up to a range of 1 km. For the same reasons as explained in the case of the BMP2/30, the probability of a BLUE kill decreases as range increases in all cases, but the rate of this decrease is much higher for the unguided weapons.

At 1.5 km in both scenarios, all BLUE systems perform comparably. Beyond this point in the defensive scenario, the LAV3/HEMi and the LAV TUA are the better options as they are more capable of killing the enemy. There is a small but noticable increase in the probability of BLUE loss at 2.5 km for the LAV3/25. This is easily explained by the fact that at this point, the AT-5 outranges the 25 mm APFSDS, so the LAV3/25 cannot defend itself against enemy fire.

In the offensive scenario, the probability of BLUE kill is near negligible beyond 2.5 km because of the difficulty of recognizing the enemy. There is therefore very little protective effect of killing the RED system before it fires. Consequently, the probability of BLUE loss is dependent primarily on the ability of the RED system to recognize and hit the BLUE system. Therefore, roughly the same probability of loss is observed for all BLUE systems at long ranges. It is slightly lower for the MGS only because it is a smaller vehicle, so it is somewhat more difficult for the enemy to recognize and hit. (It is worth noting, however, that this is a result of the vehicle dimensions that were used for this study, and that these dimensions do not consider the gun. In reality, the MGS may be more easily detected because of the large size of its gun.)

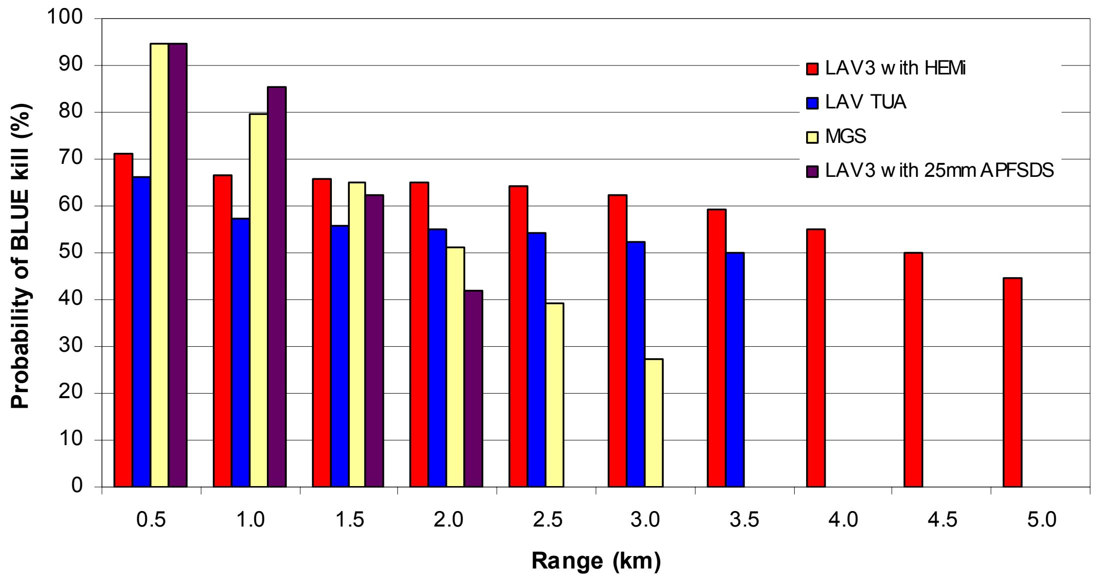

Figure 10. *BMP2 with AT-5, defensive scenario: probability of BLUE kill*

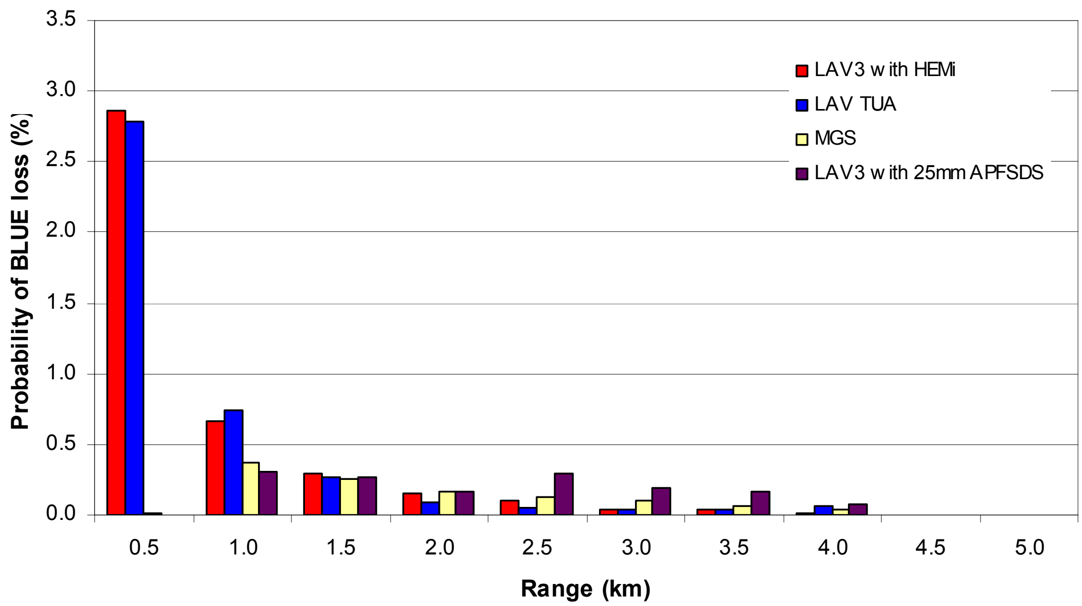

Figure 11. *BMP2 with AT-5, defensive scenario: probability of BLUE loss*

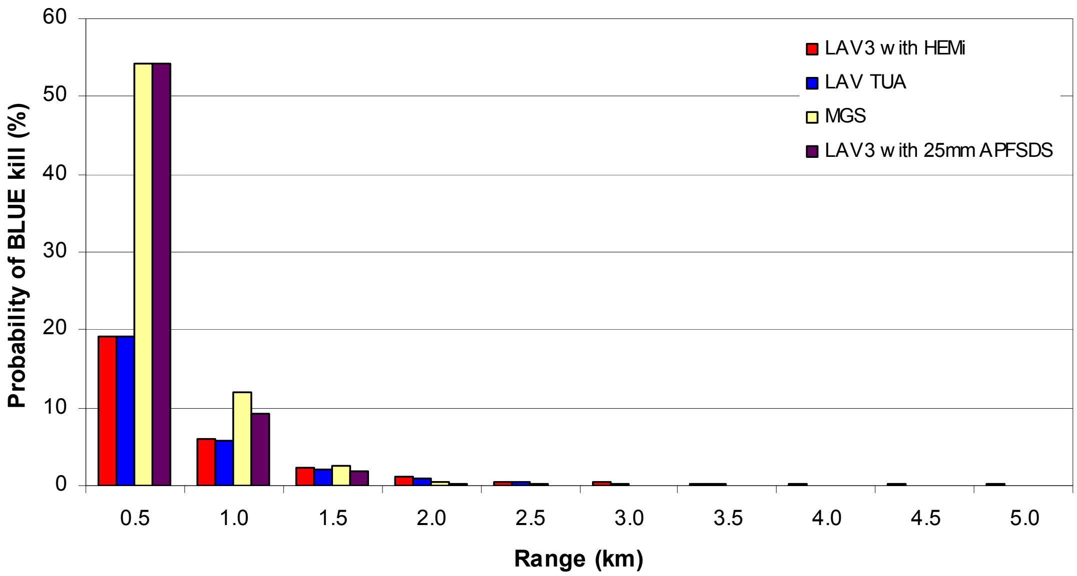

Figure 12. *BMP2 with AT-5, offensive scenario: probability of BLUE kill*

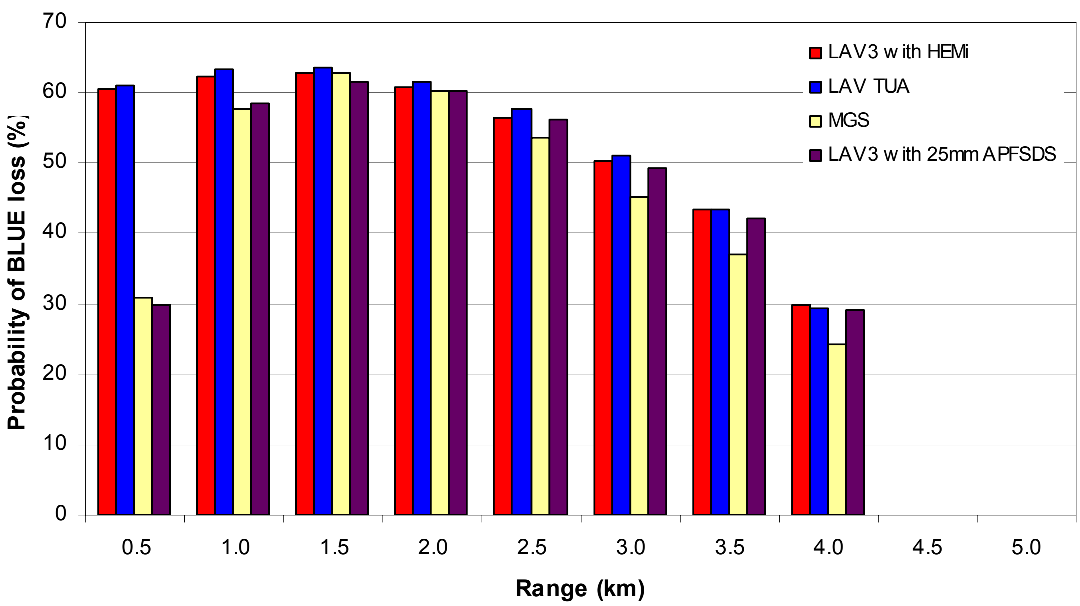

Figure 13. *BMP2 with AT-5, offensive scenario: probability of BLUE loss*

3.3 T-80U with 125 mm APFSDS

Figure 14 through Figure 17 show that the HEMi's capabilities are highly advantageous when it is used against the T-80U/125.

Comparing the probabilities of kill for the LAV3/HEMi and the LAV TUA, the advantage of the HEMi is evident. In the defensive scenario, the LAV3/HEMi performs better partly because its P_{hit} is higher. However, this does not explain why there is such a large difference in the probabilities of kill in the offensive scenario, because the two systems have the same P_{hit} values in that case. Recall that the analysis assumed that if the BLUE vehicle was hit before the missile it was guiding reached the RED target, it would lose control of the missile. Therefore, at ranges up to 2.5 km (the maximum range of the RED system), the LAV3/HEMi kills more enemies because it can reach the target sooner due to its shorter aim time and higher flight speed; consequently, the RED system is less likely to hit the BLUE vehicle (and distract its operator) while BLUE is still guiding the missile.

The probability of BLUE kill for the MGS is inferior to that of both the LAV3/HEMi and the LAV TUA. Although the P_{hit} of the 105 mm APFSDS is very high at short ranges as in the cases involving the BMP2, the $P_{kill/hit}$ is much smaller against the heavily-armoured T-80U (see Table A1). The HEMi and the TOW 2B, however, have high $P_{kill/hit}$ values even against the T-80U.

In Section 2.2, it was stated that in the model, if a vehicle was hit before it fired its weapon, it would never fire. This is one of the cases in which this assumption may have had an impact on the results. In the defensive scenario, it was found that the MGS hits but does not kill the T-80U before the T-80U fires in a maximum of 62% of the iterations. (The figure varies from 22% to 62%, depending on the range.) Although this figure is quite high, the only impact is that the probability of loss for the MGS would likely be higher than shown in Figure 15. This reflects the fact that RED would likely return fire, but with some delay, and could possibly kill BLUE. Looking at Figure 15, one might be tempted to conclude that since it is a defensive scenario, the MGS would be the best choice at a range of 500 m because it is more likely to prevent a loss. This conclusion cannot be considered valid due to the underestimation of the probability of loss of the MGS. Rather, it can be concluded that according to this analysis, the LAV3/HEMi performs the best out of the three BLUE systems because of its higher probability of kill, and, with a *possible* exception at 500 m, a lower probability of loss.

The situation described in the previous paragraph does not occur nearly as frequently in the offensive scenario. This is because, with the exception of the case of the engagement at 500 m, the stationary, partially hidden RED system most often recognizes the moving, exposed BLUE system before the BLUE recognizes the RED. It is therefore not common for BLUE to hit RED before RED fires. Furthermore, if RED subsequently fires at and hits BLUE, BLUE is almost always killed because of RED's high $P_{kill/hit}$. Thus, it is also rare that a BLUE system would be hit but not killed before firing.

In the exceptional case of the engagement at 500 m, in 33% of iterations the MGS was able to hit the T-80U/125 before the T-80U/125 could fire, but failed to kill it. This occurred only at this short range because the time required for BLUE to recognize RED is only slightly longer than the time required for RED to recognize BLUE. Also, although the two weapons have equal lay times, RED's 125 mm APFSDS has an aim time one second longer than that of the 105 mm APFSDS used by BLUE. Therefore, in this case only, it is not uncommon for the MGS to hit but not kill the T80U/125 before the T80U/125 fires. This has the same consequence as described for the defensive scenario: the probability of loss of the MGS (shown in Figure 17) is likely underestimated by the analysis. In this case, however, the conclusion is completely unaffected – even if the likely underestimation of BLUE losses is not considered, the MGS does not perform as well as the LAV3/HEMi or the LAV TUA because of its inferior probability of kill. It is safe to conclude that the LAV3/HEMi performs better than either the LAV TUA or the MGS in this analysis because the probability of kill is substantially higher than those of the other BLUE systems, and its probability of loss is, at worst, not much different than that of the MGS.

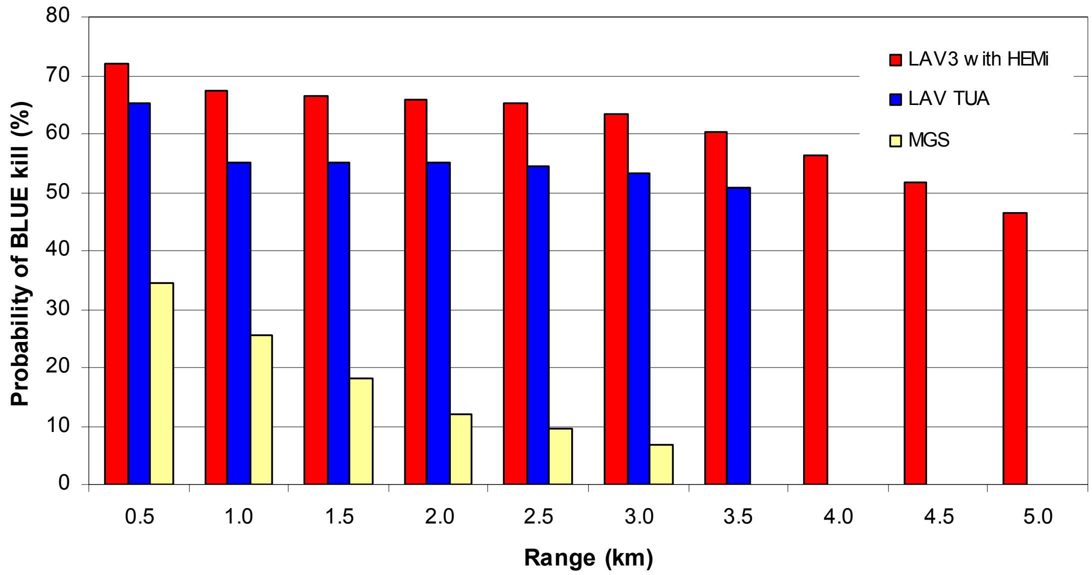

Figure 14. *T-80U with 125 mm APFSDS, defensive scenario: probability of BLUE kill*

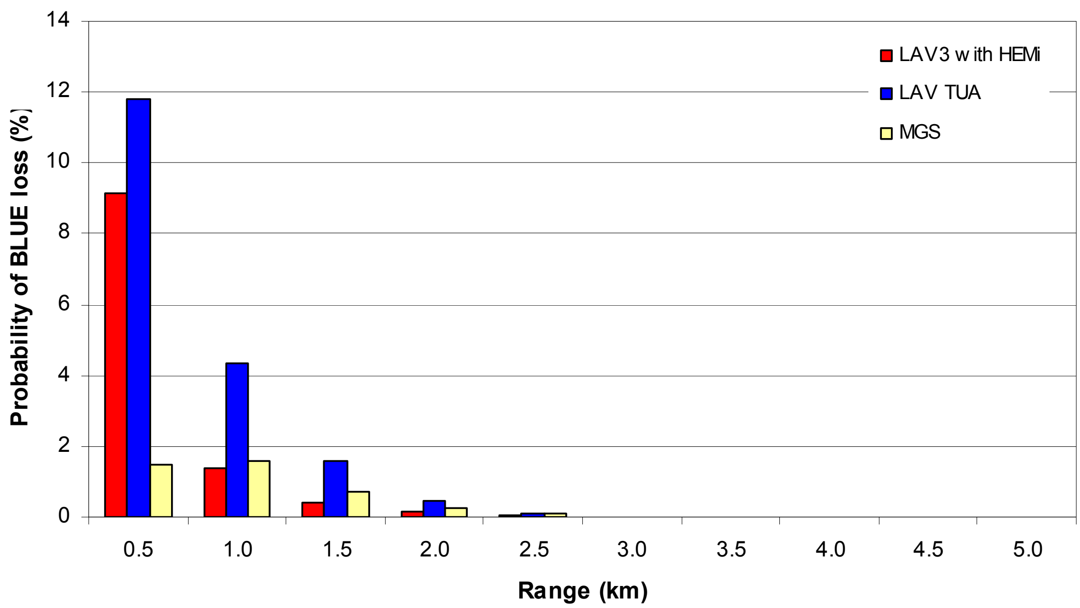

Figure 15. *T-80U with 125 mm APFSDS, defensive scenario: probability of BLUE loss*

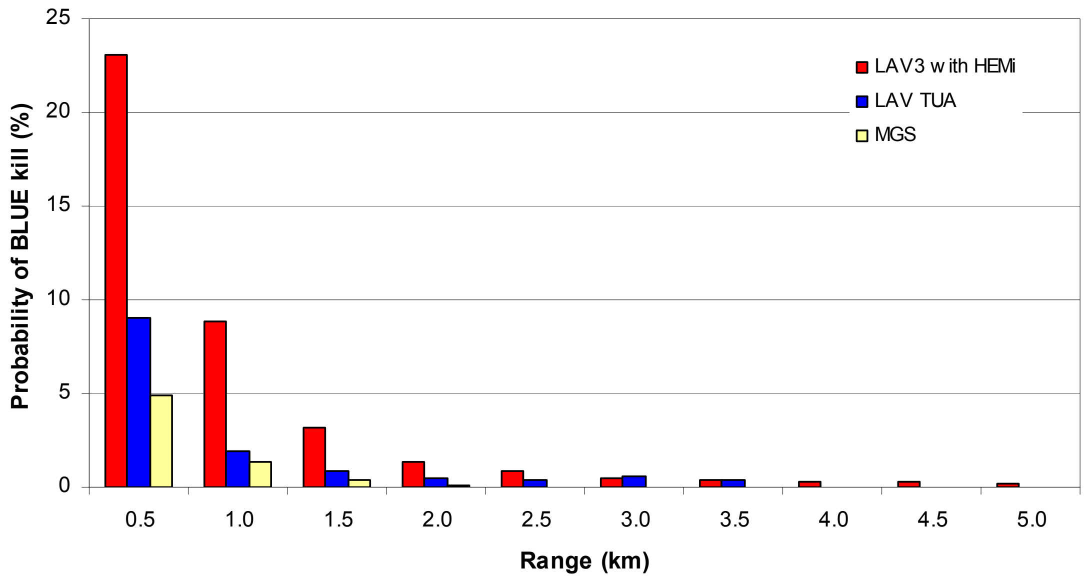

Figure 16. *T-80U with 125 mm APFSDS, offensive scenario: probability of BLUE kill*

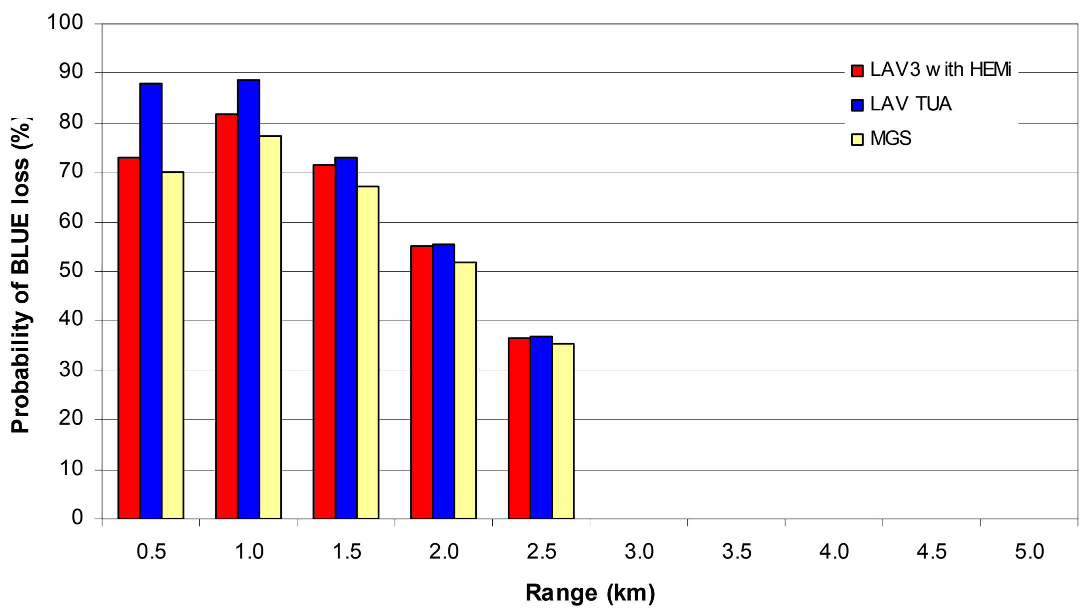

Figure 17. *T-80U with 125 mm APFSDS, offensive scenario: probability of BLUE loss*

3.4 T-80U with AT-11

As in the previous case, the HEMi's advantages are most evident when it is used against the T-80U, as shown in Figure 18 through Figure 21. Again, its probability of kill is sustantially higher than that of the LAV TUA and the MGS, especially in the offensive scenario. Out of all the RED systems considered in this study, the T80U/AT11 has the longest range (5 km); the HEMi is the only weapon that can be used at an equally long range.

The probability of loss is also lowest for the LAV3/HEMi over all ranges in the defensive scenario, and up to 1 km in the offensive scenario. Past this point, its probability of loss is slightly higher than that of the MGS. (Its killing potential, however, is much greater than that of the MGS at all ranges.)

For the same reasons described in the previous section, the probability of BLUE loss for the MGS is likely underestimated in the defensive scenario. In 22% to 52% of cases (depending on range), the MGS was able to hit but not kill the T80U/AT11 before it fired. Again, the conclusion is unchanged: in this analysis the MGS does not perform as well as either the LAV3/HEMi or the LAV TUA. This is true for both the defensive and offensive scenarios.

It is interesting to highlight the significance of the lay and aim times when looking at the probabilities of kill and loss in the offensive scenario (Figure 20). Here, the LAV3/HEMi and the LAV TUA have the same P_{hit} and the same $P_{kill/hit}$, up to the LAV TUA's maximum range of 3.75 km. The two systems are also equally vulnerable to enemy fire. Therefore, any performance differences can be attributed only to differences in the lay time, the aim time, and the time of flight between the two BLUE weapons. Figure 20 shows that the LAV3/HEMi has a much higher probability of kill than the LAV TUA. This is because the sum of its lay and aim times is shorter. Its time of flight is also shorter, but this difference is negligible at short ranges. Because of this temporal advantage, the LAV3/HEMi is more often able to reach its target before being hit itself. This is important because the HEMi and the TOW 2B are both guided missiles; as stated earlier, it was assumed that a guided missile will not hit its target if its host vehicle is hit first.

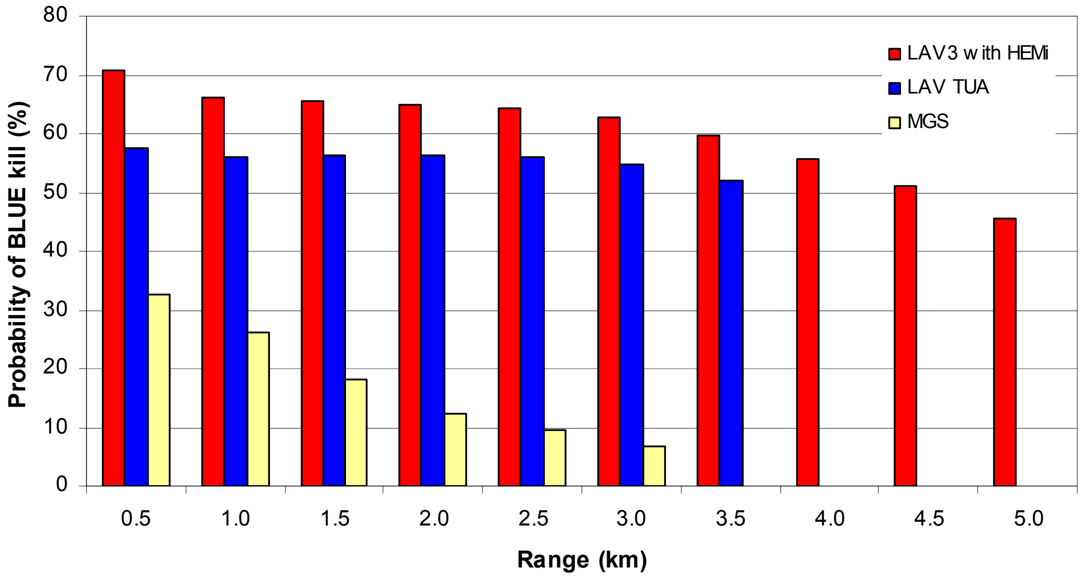

Figure 18. *T-80U with AT-11, defensive scenario: probability of BLUE kill*

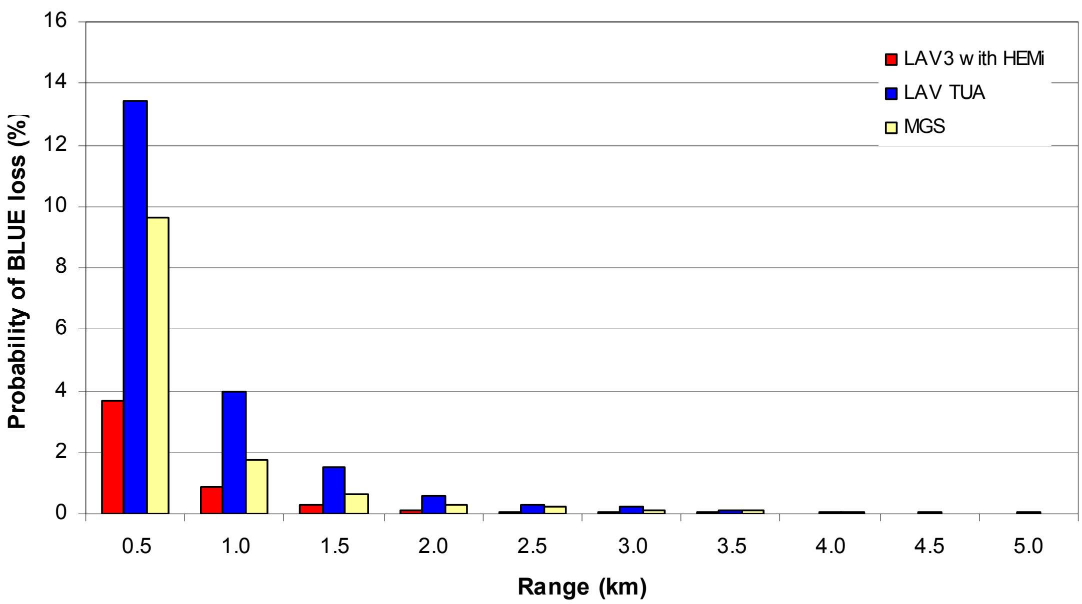

Figure 19. *T-80U with AT-11, defensive scenario: probability of BLUE loss*

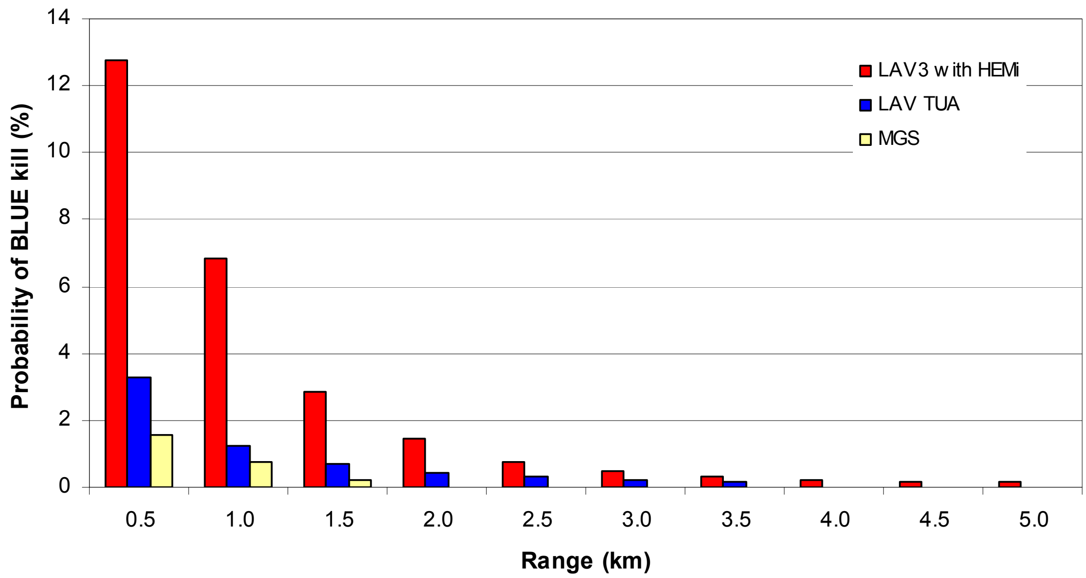

Figure 20. *T-80U with AT-11, offensive scenario: probability of BLUE kill*

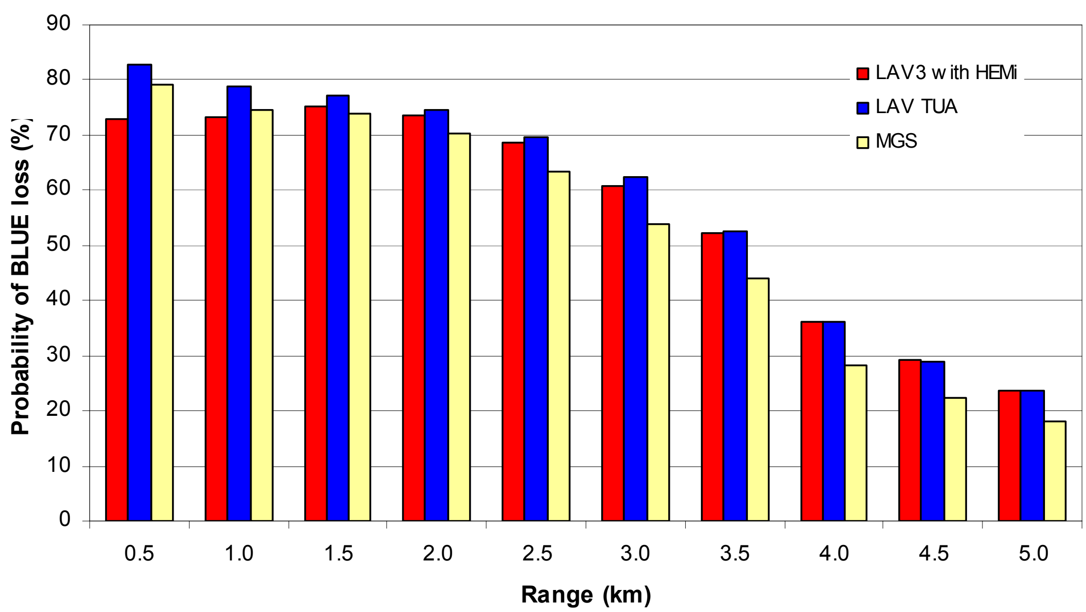

Figure 21. *T-80U with AT-11, offensive scenario: probability of BLUE loss*

4. Conclusions and recommendations

Owing to the many limitations of this study, there is not a great deal of value in the absolute numerical results obtained. However, there is some value in the comparative performance of the BLUE systems on a broader scale. Even so, it is important to keep in mind that some of the conclusions presented here could be invalidated if the underlying assumptions are invalid, or if new information concerning the weapon parameters becomes available. The lay and aim times of the HEMi as well as the $P_{kill/hit}$ for all weapons are particularly uncertain.

The LAV3/HEMi is the best system for long-range engagements. The HEMi is the only BLUE weapon considered in this study that is effective beyond 3.75 km. This is particularly important in cases where the RED vehicle carries a long-range weapon (AT-5 and AT-11), as the BLUE vehicle will be extremely vulnerable if it has no long-range weapon.

The LAV3/HEMi is the most effective system against the T-80U. In terms of kill capability, the LAV3/HEMi performs better than any of the other BLUE systems considered. This is due to its consistently high P_{hit} and $P_{kill/hit}$ values, and because of its shorter aim time and shorter time of flight. Its ability to deliver fire to the enemy sooner reduces the likelihood of being killed.

The LAV3/HEMi is not the best choice for short-range engagements against the BMP2. Because of their very high P_{hit} values at short ranges, the MGS and LAV3/25 are preferable out to 1 km. Beyond 1.5 km, all BLUE systems studied perform fairly comparably.

The 25mm APFSDS could be an effective weapon to use alongside the HEMi on a LAV3. It could be used for softer targets at short range, while the HEMi could be reserved for harder targets and longer-range targets. This would be especially effective considering the limited number of HEMi rounds that the host vehicle could probably carry. Furthermore, the cost of the HEMi is sure to be far greater than that of the 25 mm APFSDS, so it would be more sensible economically to use the 25 mm round wherever its capabilities are adequate.

This study also highlights the complexity of an engagement between two vehicles. It is reasonably easy to identify the factors that will determine the winner of the engagement, but how the factors interact is not as obvious. Only some of factors could be considered in this study. These were the time required to detect and recognize the enemy, the lay and aim times of the system, the time of flight of the round, the probability of hit, and the probability of kill given a hit. Factors that were not considered include human factors such as the training and fatigue of the operator, atmospheric conditions, and the presence of additional sensors. Clearly, the complexity would increase if all contributing factors were accounted for, and it would increase much further in a scenario involving more than two vehicles, all of which

would interact with each other in some way. The study illustrates that evaluating a weapon system can be more complicated than it may appear at first glance.

If further OR work concerning the HEMi is desired, this study could easily be replicated if more accurate data on lay and aim times, P_{hit} and/or $P_{kill/hit}$ become available; however, many of the limitations outlined in this document would remain.

A more conclusive but more resource-consuming option would be to conduct a war game. This could be done either through constructive simulation at the Directorate of Land Synthetic Environments (DLSE) in Kingston, Ontario, or through live simulation using the Weapons Effects Simulation (WES) system in Wainwright, Alberta.

5. References

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7. *Janus Version 7.06D Documentation, Volume 4: Software Algorithms*. Tradoc Analysis Center – WSMR. July 2000.

Annex A

Table A1. *P_{hit} and $P_{kill/hit}$*

Range	Defensive Scenario (RED attacks)					Offensive Scenario (BLUE attacks)				
	BLUE			RED		BLUE		RED		
	P_{hit} (tgt mov)	P_{hit} (tgt stat)	$P_{kill/hit}$	P_{hit}	$P_{kill/hit}$	P_{hit}	$P_{kill/hit}$	P_{hit} (tgt mov)	P_{hit} (tgt stat)	$P_{kill/hit}$
LAV3 with HEMi vs BMP2 with 30 mm APDS-T										
0.0	0.69	0.80	0.95	0.29	0.95	0.27	0.95	1.00	1.00	0.95
0.5	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.99	1.00	0.95
1.0	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.77	0.86	0.90
1.5	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.38	0.50	0.74
2.0	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.00	0.00	0.00
2.5	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.00	0.00	0.00
3.0	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.00	0.00	0.00
3.5	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.00	0.00	0.00
4.0	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.00	0.00	0.00
4.5	0.69	0.80	0.95	0.00	0.00	0.27	0.95	0.00	0.00	0.00
5.0	0.69	0.80	0.95	0.00	0.00	0.27	0.95	0.00	0.00	0.00
LAV3 with HEMi vs BMP2 with AT-5										
0.0	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
0.5	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
1.0	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
1.5	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
2.0	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
2.5	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
3.0	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
3.5	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
4.0	0.69	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
4.5	0.69	0.80	0.95	0.00	0.00	0.27	0.95	0.00	0.00	0.00
5.0	0.69	0.80	0.95	0.00	0.00	0.27	0.95	0.00	0.00	0.00
LAV3 with HEMi vs T80U with 125 mm APFSDS										
0.0	0.69	0.81	0.95	1.00	0.95	0.37	0.95	1.00	1.00	0.95
0.5	0.69	0.81	0.95	0.93	0.95	0.37	0.95	1.00	1.00	0.95
1.0	0.69	0.81	0.95	0.57	0.95	0.37	0.95	0.93	0.98	0.95
1.5	0.69	0.81	0.95	0.42	0.95	0.37	0.95	0.77	0.86	0.95
2.0	0.69	0.81	0.95	0.27	0.95	0.37	0.95	0.60	0.74	0.95
2.5	0.69	0.81	0.95	0.13	0.95	0.37	0.95	0.44	0.62	0.95
3.0	0.69	0.81	0.95	0.00	0.00	0.37	0.95	0.00	0.00	0.00
3.5	0.69	0.81	0.95	0.00	0.00	0.37	0.95	0.00	0.00	0.00
4.0	0.69	0.81	0.95	0.00	0.00	0.37	0.95	0.00	0.00	0.00
4.5	0.69	0.81	0.95	0.00	0.00	0.37	0.95	0.00	0.00	0.00
5.0	0.69	0.81	0.95	0.00	0.00	0.37	0.95	0.00	0.00	0.00

Range	Defensive Scenario (RED attacks)					Offensive Scenario (BLUE attacks)				
	BLUE			RED		BLUE		RED		
	P_{hit} (tgt mov)	P_{hit} (tgt stat)	$P_{kill/hit}$	P_{hit}	$P_{kill/hit}$	P_{hit}	$P_{kill/hit}$	P_{hit} (tgt mov)	P_{hit} (tgt stat)	$P_{kill/hit}$
LAV3 with HEMi vs T80U with AT-11										
0.0	0.69	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
0.5	0.69	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
1.0	0.69	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
1.5	0.69	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
2.0	0.69	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
2.5	0.69	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
3.0	0.69	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
3.5	0.69	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
4.0	0.69	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
4.5	0.69	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
5.0	0.69	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
LAV TUA vs BMP2 with 30 mm APDS-T										
0.0	0.59	0.80	0.95	1.00	0.95	0.27	0.95	1.00	1.00	0.95
0.5	0.59	0.80	0.95	0.90	0.95	0.27	0.95	0.99	1.00	0.95
1.0	0.59	0.80	0.95	0.36	0.95	0.27	0.95	0.77	0.86	0.90
1.5	0.59	0.80	0.95	0.12	0.95	0.27	0.95	0.38	0.50	0.74
2.0	0.59	0.80	0.95	0.00	0.00	0.27	0.95	0.00	0.00	0.00
2.5	0.59	0.80	0.95	0.00	0.00	0.27	0.95	0.00	0.00	0.00
3.0	0.59	0.80	0.95	0.00	0.00	0.27	0.95	0.00	0.00	0.00
3.5	0.59	0.80	0.95	0.00	0.00	0.27	0.95	0.00	0.00	0.00
4.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAV TUA vs BMP2 with AT-5										
0.0	0.59	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
0.5	0.59	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
1.0	0.59	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
1.5	0.59	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
2.0	0.59	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
2.5	0.59	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
3.0	0.59	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
3.5	0.59	0.80	0.95	0.29	0.95	0.27	0.95	0.67	0.85	0.95
4.0	0.00	0.00	0.00	0.29	0.95	0.00	0.00	0.67	0.85	0.95
4.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Defensive Scenario (RED attacks)					***Offensive Scenario (BLUE attacks)***				
	BLUE			***RED***		***BLUE***		***RED***		
Range	P_{hit} ***(tgt mov)***	P_{hit} ***(tgt stat)***	$P_{kill/hit}$	P_{hit}	$P_{kill/hit}$	P_{hit}	$P_{kill/hit}$	P_{hit} ***(tgt mov)***	P_{hit} ***(tgt stat)***	$P_{kill/hit}$
LAV TUA vs T80U with 125 mm APFSDS										
0.0	0.59	0.81	0.95	1.00	0.95	0.37	0.95	1.00	1.00	0.95
0.5	0.59	0.81	0.95	0.93	0.95	0.37	0.95	1.00	1.00	0.95
1.0	0.59	0.81	0.95	0.57	0.95	0.37	0.95	0.93	0.98	0.95
1.5	0.59	0.81	0.95	0.42	0.95	0.37	0.95	0.77	0.86	0.95
2.0	0.59	0.81	0.95	0.27	0.95	0.37	0.95	0.60	0.74	0.95
2.5	0.59	0.81	0.95	0.13	0.95	0.37	0.95	0.44	0.62	0.95
3.0	0.59	0.81	0.95	0.00	0.00	0.37	0.95	0.00	0.00	0.00
3.5	0.59	0.81	0.95	0.00	0.00	0.37	0.95	0.00	0.00	0.00
4.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAV TUA vs T80U with AT11										
0.0	0.59	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
0.5	0.59	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
1.0	0.59	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
1.5	0.59	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
2.0	0.59	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
2.5	0.59	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
3.0	0.59	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
3.5	0.59	0.81	0.95	0.36	0.95	0.37	0.95	0.81	0.89	0.95
4.0	0.00	0.00	0.00	0.36	0.95	0.00	0.00	0.81	0.89	0.95
4.5	0.00	0.00	0.00	0.36	0.95	0.00	0.00	0.81	0.89	0.95
5.0	0.00	0.00	0.00	0.36	0.95	0.00	0.00	0.81	0.89	0.95
MGS vs BMP2 with 30 mm APDS-T										
0.0	1.00	1.00	0.95	1.00	0.95	1.00	0.95	1.00	1.00	0.93
0.5	1.00	1.00	0.95	0.79	0.95	0.74	0.95	0.93	0.95	0.81
1.0	0.85	0.87	0.95	0.33	0.95	0.54	0.95	0.75	0.84	0.73
1.5	0.69	0.73	0.95	0.13	0.95	0.35	0.95	0.39	0.50	0.73
2.0	0.54	0.60	0.95	0.00	0.00	0.15	0.95	0.00	0.00	0.00
2.5	0.42	0.48	0.95	0.00	0.00	0.11	0.95	0.00	0.00	0.00
3.0	0.30	0.36	0.95	0.00	0.00	0.07	0.95	0.00	0.00	0.00
3.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Range	Defensive Scenario (RED attacks)					Offensive Scenario (BLUE attacks)				
	BLUE			RED		BLUE		RED		
	P_{hit} (tgt mov)	P_{hit} (tgt stat)	$P_{kill/hit}$	P_{hit}	$P_{kill/hit}$	P_{hit}	$P_{kill/hit}$	P_{hit} (tgt mov)	P_{hit} (tgt stat)	$P_{kill/hit}$
MGS vs BMP2 with AT5										
0.0	1.00	1.00	0.95	0.32	0.95	1.00	0.95	0.67	0.83	0.95
0.5	1.00	1.00	0.95	0.32	0.95	0.74	0.95	0.67	0.83	0.95
1.0	0.85	0.87	0.95	0.32	0.95	0.54	0.95	0.67	0.83	0.95
1.5	0.69	0.73	0.95	0.32	0.95	0.35	0.95	0.67	0.83	0.95
2.0	0.54	0.60	0.95	0.32	0.95	0.15	0.95	0.67	0.83	0.95
2.5	0.42	0.48	0.95	0.32	0.95	0.11	0.95	0.67	0.83	0.95
3.0	0.30	0.36	0.95	0.32	0.95	0.07	0.95	0.67	0.83	0.95
3.5	0.00	0.00	0.00	0.32	0.95	0.00	0.00	0.67	0.83	0.95
4.0	0.00	0.00	0.00	0.32	0.95	0.00	0.00	0.67	0.83	0.95
4.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MGS vs T80U with 125 mm APFSDS										
0.0	1.00	1.00	0.46	1.00	0.95	1.00	0.25	1.00	1.00	0.95
0.5	1.00	1.00	0.36	0.85	0.95	0.85	0.15	0.96	0.98	0.95
1.0	0.85	0.87	0.31	0.53	0.95	0.64	0.11	0.87	0.93	0.95
1.5	0.69	0.74	0.26	0.41	0.95	0.43	0.08	0.73	0.83	0.95
2.0	0.54	0.60	0.22	0.28	0.95	0.22	0.05	0.58	0.72	0.95
2.5	0.42	0.48	0.22	0.16	0.95	0.17	0.05	0.44	0.62	0.95
3.0	0.31	0.36	0.22	0.00	0.00	0.11	0.05	0.00	0.00	0.00
3.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MGS vs T80U with AT11										
0.0	1.00	1.00	0.46	0.38	0.95	1.00	0.25	0.80	0.86	0.95
0.5	1.00	1.00	0.36	0.38	0.95	0.85	0.15	0.80	0.86	0.95
1.0	0.85	0.87	0.31	0.38	0.95	0.64	0.11	0.80	0.86	0.95
1.5	0.69	0.74	0.26	0.38	0.95	0.43	0.08	0.80	0.86	0.95
2.0	0.54	0.60	0.22	0.38	0.95	0.22	0.05	0.80	0.86	0.95
2.5	0.42	0.48	0.22	0.38	0.95	0.17	0.05	0.80	0.86	0.95
3.0	0.31	0.36	0.22	0.38	0.95	0.11	0.05	0.80	0.86	0.95
3.5	0.00	0.00	0.00	0.38	0.95	0.00	0.00	0.80	0.86	0.95
4.0	0.00	0.00	0.00	0.38	0.95	0.00	0.00	0.80	0.86	0.95
4.5	0.00	0.00	0.00	0.38	0.95	0.00	0.00	0.80	0.86	0.95
5.0	0.00	0.00	0.00	0.38	0.95	0.00	0.00	0.80	0.86	0.95

Range	Defensive Scenario					Offensive Scenario				
	BLUE			RED		BLUE		RED		
	P_{hit} (tgt mov)	P_{hit} (tgt stat)	$P_{kill/hit}$	P_{hit}	$P_{kill/hit}$	P_{hit}	$P_{kill/hit}$	P_{hit} (tgt mov)	P_{hit} (tgt stat)	$P_{kill/hit}$
LAV3 with 25 mm APFSDS vs BMP2 with 30 mm APDS-T										
0.0	1.00	1.00	0.95	1.00	0.95	1.00	0.95	1.00	1.00	0.95
0.5	1.00	1.00	0.95	0.90	0.95	0.75	0.95	0.99	1.00	0.95
1.0	0.90	0.93	0.95	0.36	0.95	0.42	0.95	0.77	0.86	0.90
1.5	0.70	0.74	0.90	0.12	0.95	0.29	0.68	0.38	0.50	0.74
2.0	0.50	0.54	0.85	0.00	0.00	0.15	0.41	0.00	0.00	0.00
2.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAV3 with 25 mm APFSDS vs BMP2 with AT5										
0.0	1.00	1.00	0.95	0.29	0.95	1.00	0.95	0.67	0.85	0.95
0.5	1.00	1.00	0.95	0.29	0.95	0.75	0.95	0.67	0.85	0.95
1.0	0.90	0.93	0.95	0.29	0.95	0.42	0.95	0.67	0.85	0.95
1.5	0.70	0.74	0.90	0.29	0.95	0.29	0.68	0.67	0.85	0.95
2.0	0.50	0.54	0.85	0.29	0.95	0.15	0.41	0.67	0.85	0.95
2.5	0.00	0.00	0.00	0.29	0.95	0.00	0.00	0.67	0.85	0.95
3.0	0.00	0.00	0.00	0.29	0.95	0.00	0.00	0.67	0.85	0.95
3.5	0.00	0.00	0.00	0.29	0.95	0.00	0.00	0.67	0.85	0.95
4.0	0.00	0.00	0.00	0.29	0.95	0.00	0.00	0.67	0.85	0.95
4.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Annex B

Table B1. *Outcome of engagement*

EVENT SEQUENCE				B GUIDED R GUIDED	B UNGUIDED R UNGUIDED	B UNGUIDED R GUIDED	B GUIDED R UNGUIDED
B fires	R fires	B hits/kills	R hits/kills	BLUE	DEAD	BLUE	DEAD
B fires	R fires	B hits/kills	R hits/doesn't kill	BLUE	BLUE	BLUE	BLUE
B fires	R fires	B hits/kills	R misses	BLUE	BLUE	BLUE	BLUE
B fires	R fires	B hits/doesn't kill	R hits/kills	ALIVE	RED	ALIVE	RED
B fires	R fires	B hits/doesn't kill	R hits/doesn't kill	ALIVE	ALIVE	ALIVE	ALIVE
B fires	R fires	B hits/doesn't kill	R misses	ALIVE	ALIVE	ALIVE	ALIVE
B fires	R fires	B misses	R hits/kills	RED	RED	RED	RED
B fires	R fires	B misses	R hits/doesn't kill	ALIVE	ALIVE	ALIVE	ALIVE
B fires	R fires	B misses	R misses	ALIVE	ALIVE	ALIVE	ALIVE
B fires	R fires	R hits/kills	B hits/kills	RED	DEAD	DEAD	RED
B fires	R fires	R hits/doesn't kill	B hits/kills	ALIVE	BLUE	BLUE	ALIVE
B fires	R fires	R misses	B hits/kills	BLUE	BLUE	BLUE	BLUE
B fires	R fires	R hits/kills	B hits/doesn't kill	RED	RED	RED	RED
B fires	R fires	R hits/doesn't kill	B hits/doesn't kill	ALIVE	ALIVE	ALIVE	ALIVE
B fires	R fires	R misses	B hits/doesn't kill	ALIVE	ALIVE	ALIVE	ALIVE
B fires	R fires	R hits/kills	B misses	RED	RED	RED	RED
B fires	R fires	R hits/doesn't kill	B misses	ALIVE	ALIVE	ALIVE	ALIVE
B fires	R fires	R misses	B misses	ALIVE	ALIVE	ALIVE	ALIVE
B fires	B hits/kills	R fires	R hits/kills	BLUE	BLUE	BLUE	BLUE
B fires	B hits/kills	R fires	R hits/doesn't kill	BLUE	BLUE	BLUE	BLUE
B fires	B hits/kills	R fires	R misses	BLUE	BLUE	BLUE	BLUE
B fires	B hits/doesn't kill	R fires	R hits/kills	ALIVE	ALIVE	ALIVE	ALIVE
B fires	B hits/doesn't kill	R fires	R hits/doesn't kill	ALIVE	ALIVE	ALIVE	ALIVE
B fires	B hits/doesn't kill	R fires	R misses	ALIVE	ALIVE	ALIVE	ALIVE
B fires	B misses	R fires	R hits/kills	RED	RED	RED	RED
B fires	B misses	R fires	R hits/doesn't kill	ALIVE	ALIVE	ALIVE	ALIVE
B fires	B misses	R fires	R misses	ALIVE	ALIVE	ALIVE	ALIVE
R fires	B fires	R hits/kills	B hits/kills	RED	DEAD	DEAD	RED
R fires	B fires	R hits/doesn't kill	B hits/kills	ALIVE	BLUE	BLUE	ALIVE
R fires	B fires	R misses	B hits/kills	BLUE	BLUE	BLUE	BLUE
R fires	B fires	R hits/kills	B hits/doesn't kill	RED	RED	RED	RED
R fires	B fires	R hits/doesn't kill	B hits/doesn't kill	ALIVE	ALIVE	ALIVE	ALIVE
R fires	B fires	R misses	B hits/doesn't kill	ALIVE	ALIVE	ALIVE	ALIVE
R fires	B fires	R hits/kills	B misses	RED	RED	RED	RED
R fires	B fires	R hits/doesn't kill	B misses	ALIVE	ALIVE	ALIVE	ALIVE
R fires	B fires	R misses	B misses	ALIVE	ALIVE	ALIVE	ALIVE
R fires	B fires	B hits/kills	R hits/kills	BLUE	DEAD	BLUE	DEAD
R fires	B fires	B hits/kills	R hits/doesn't kill	BLUE	BLUE	BLUE	BLUE
R fires	B fires	B hits/kills	R misses	BLUE	BLUE	BLUE	BLUE
R fires	B fires	B hits/doesn't kill	R hits/kills	ALIVE	RED	ALIVE	RED
R fires	B fires	B hits/doesn't kill	R hits/doesn't kill	ALIVE	ALIVE	ALIVE	ALIVE
R fires	B fires	B hits/doesn't kill	R misses	ALIVE	ALIVE	ALIVE	ALIVE
R fires	B fires	B misses	R hits/kills	RED	RED	RED	RED
R fires	B fires	B misses	R hits/doesn't kill	ALIVE	ALIVE	ALIVE	ALIVE
R fires	B fires	B misses	R misses	ALIVE	ALIVE	ALIVE	ALIVE

RED = RED alive, BLUE dead; BLUE = BLUE alive, RED dead; ALIVE = both alive; DEAD = both dead

EVENT SEQUENCE				B GUIDED R GUIDED	B UNGUIDED R UNGUIDED	B UNGUIDED R GUIDED	B GUIDED R UNGUIDED
R fires	R hits/kills	B fires	B hits/kills	RED	RED	RED	RED
R fires	R hits/doesn't kill	B fires	B hits/kills	ALIVE	ALIVE	ALIVE	ALIVE
R fires	R misses	B fires	B hits/kills	BLUE	BLUE	BLUE	BLUE
R fires	R hits/kills	B fires	B hits/doesn't kill	RED	RED	RED	RED
R fires	R hits/doesn't kill	B fires	B hits/doesn't kill	ALIVE	ALIVE	ALIVE	ALIVE
R fires	R misses	B fires	B hits/doesn't kill	ALIVE	ALIVE	ALIVE	ALIVE
R fires	R hits/kills	B fires	B misses	RED	RED	RED	RED
R fires	R hits/doesn't kill	B fires	B misses	ALIVE	ALIVE	ALIVE	ALIVE
R fires	R misses	B fires	B misses	ALIVE	ALIVE	ALIVE	ALIVE

RED = RED alive, BLUE dead; BLUE = BLUE alive, RED dead; ALIVE = both alive; DEAD = both dead

Annex C

The floating points in the graphs below indicate an LER of infinity, which occurred when there were no BLUE losses for that case. This was normally a result of being out of range of RED's weapon.

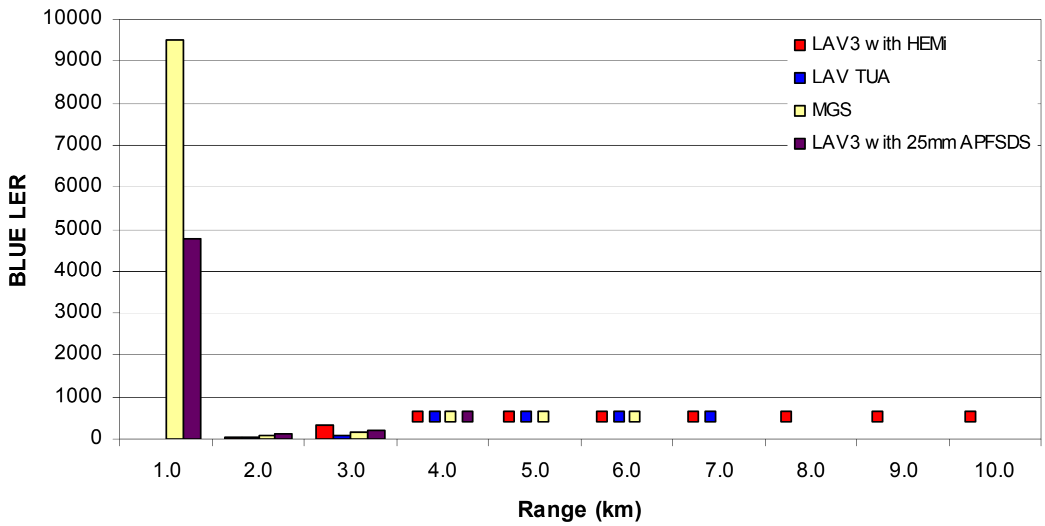

Figure C1. *BMP2 with 30 mm APDS-T, defensive scenario: LER*

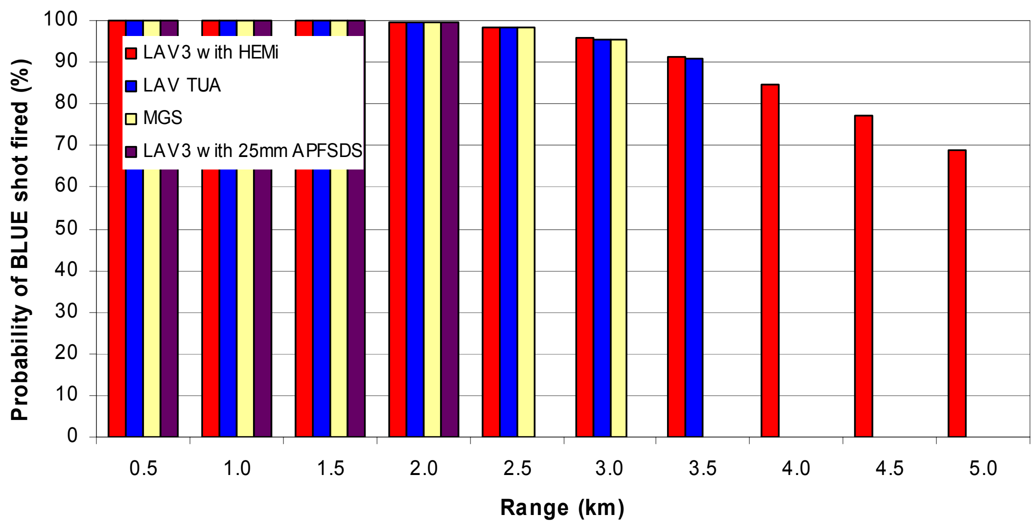

Figure C2. *BMP2 with 30 mm APDS-T, defensive scenario: probability of BLUE shot fired*

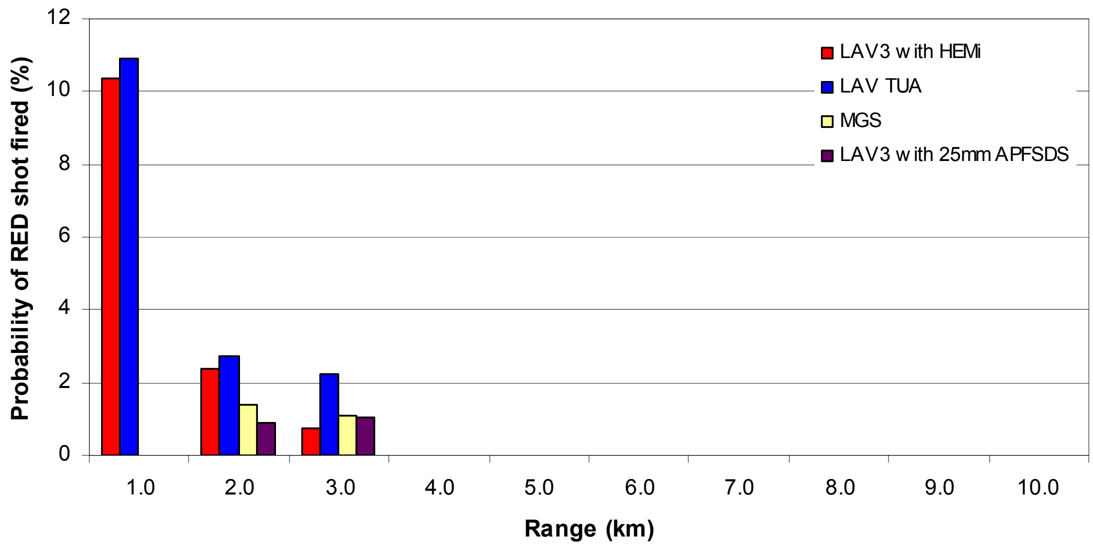

Figure C3. *BMP2 with 30 mm APDS-T, defensive scenario: probability of RED shot fired*

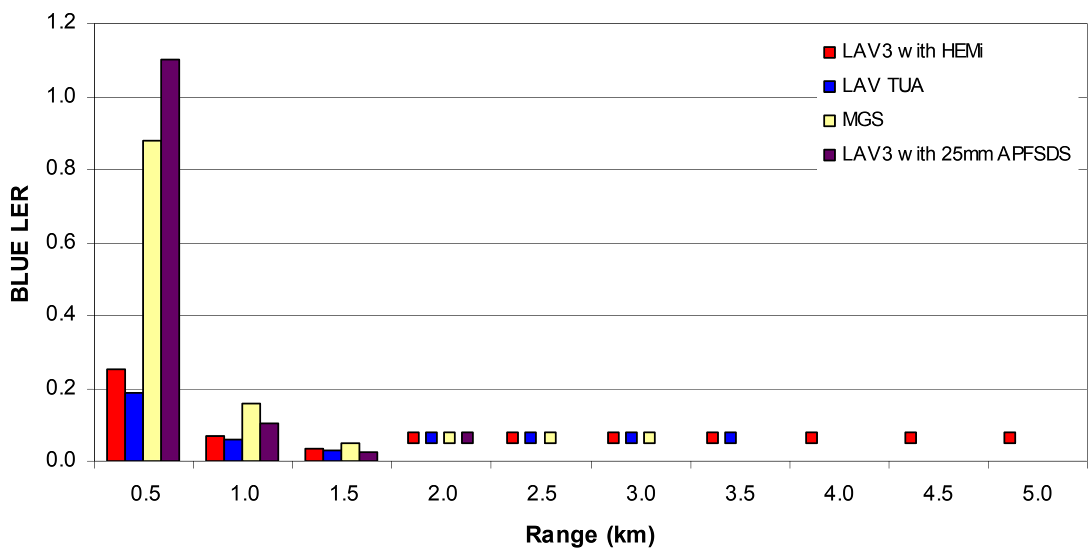

Figure C4. *BMP2 with 30mm APDS-T, offensive scenario: LER*

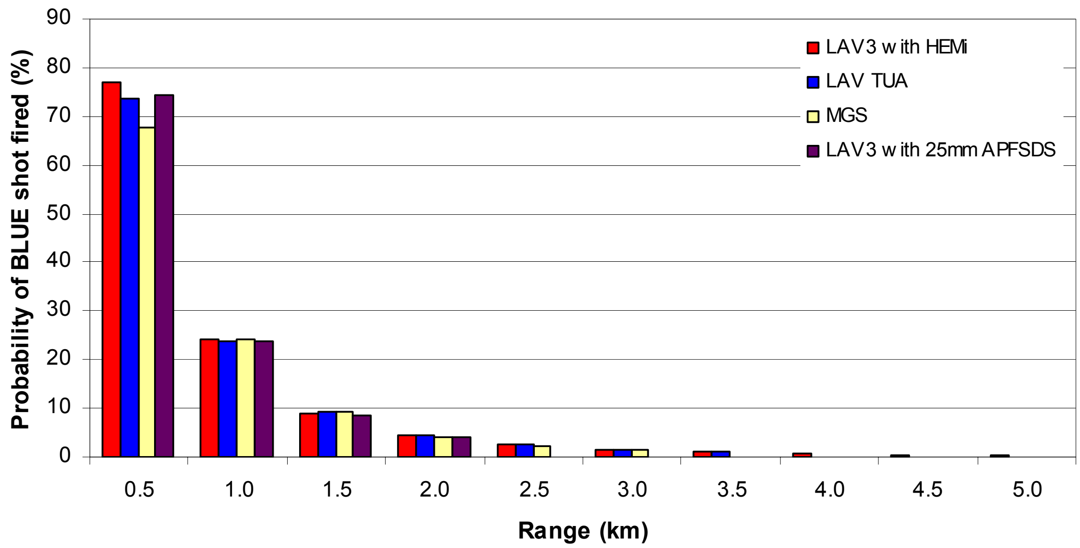

Figure C5. *BMP2 with 30mm APDS-T, offensive scenario: probability of BLUE shot fired*

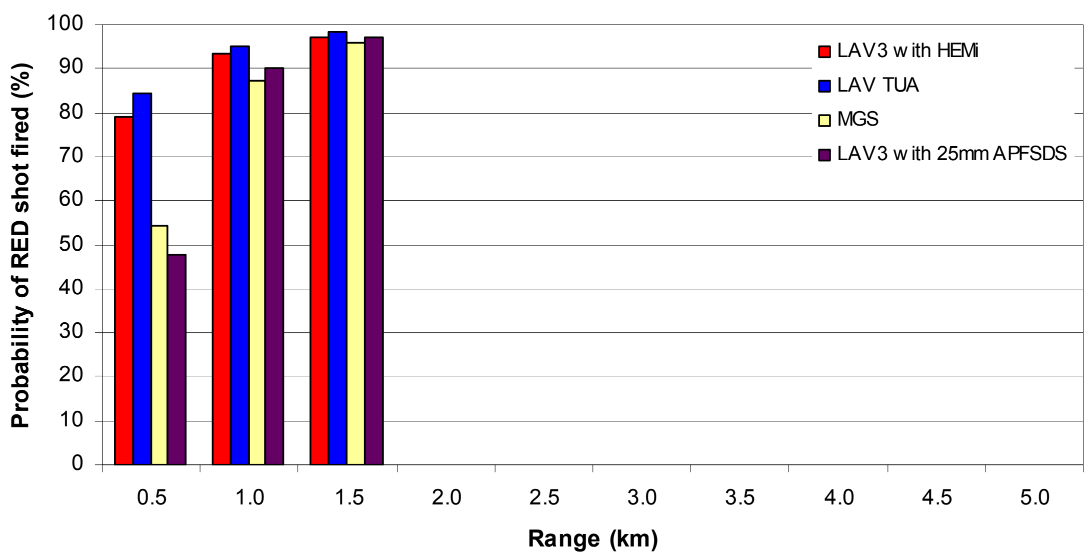

Figure C6. *BMP2 with 30mm APDS-T, offensive scenario: probability of RED shot fired*

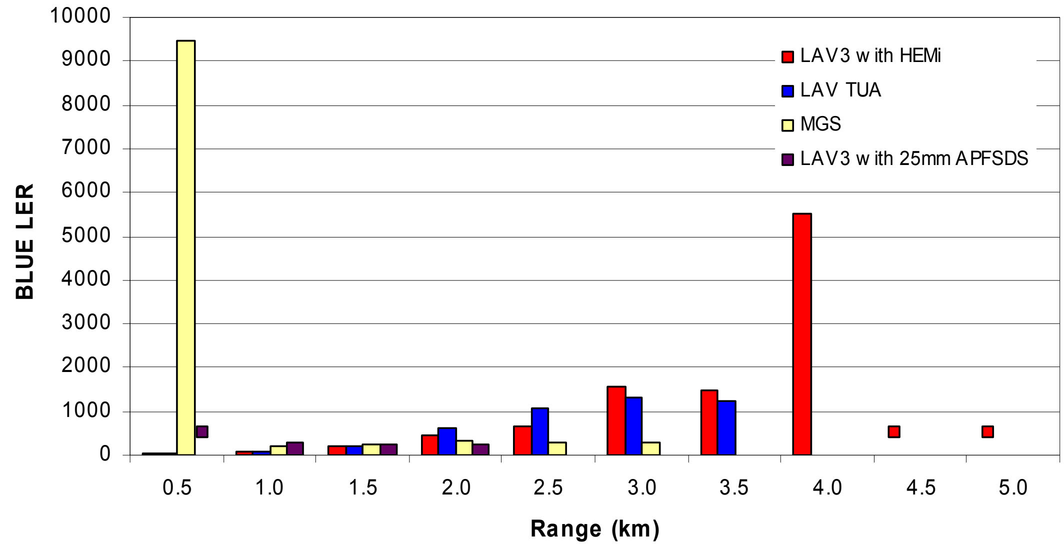

Figure C7. *BMP2 with AT-5, defensive scenario: LER*

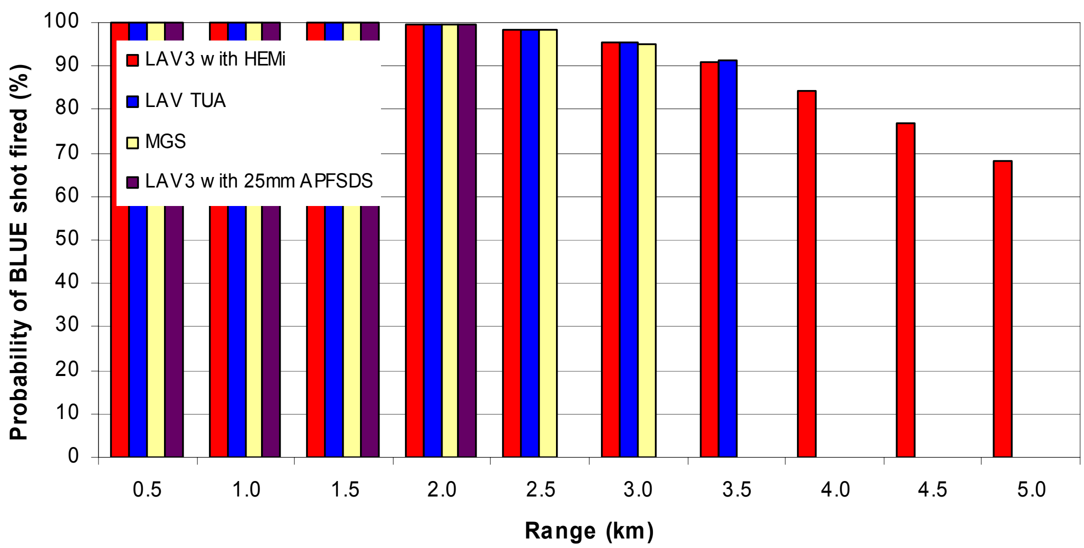

Figure C8. *BMP2 with AT-5, defensive scenario: probability of BLUE shot fired*

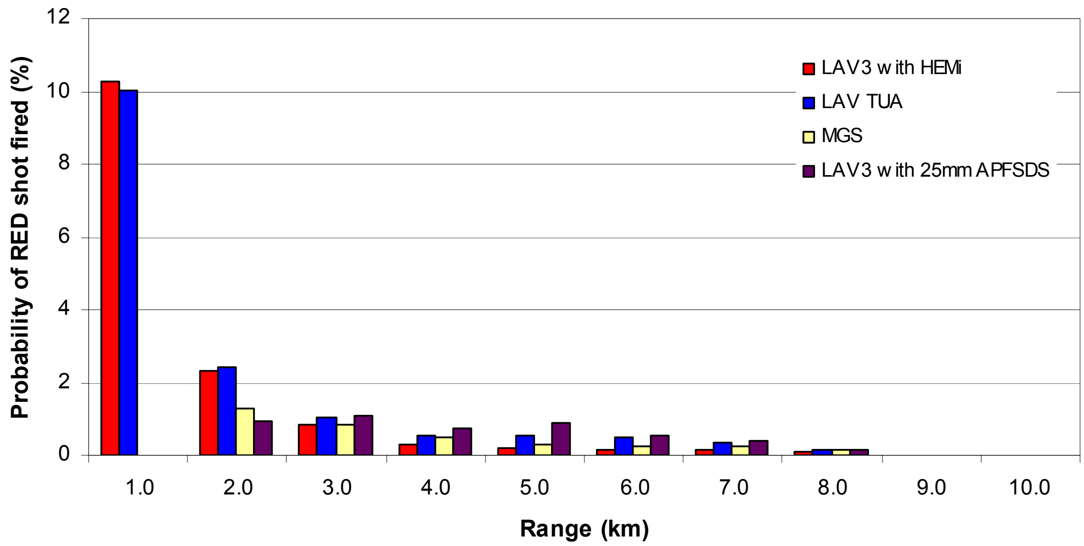

Figure C9. *BMP2 with AT-5, defensive scenario: probability of RED shot fired*

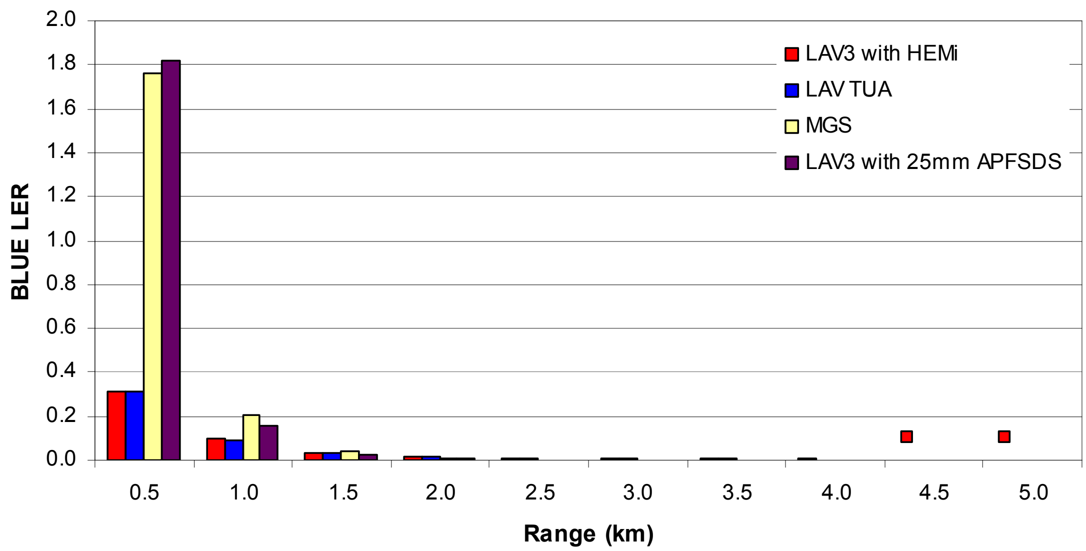

Figure C10. *BMP2 with AT-5, offensive scenario: LER*

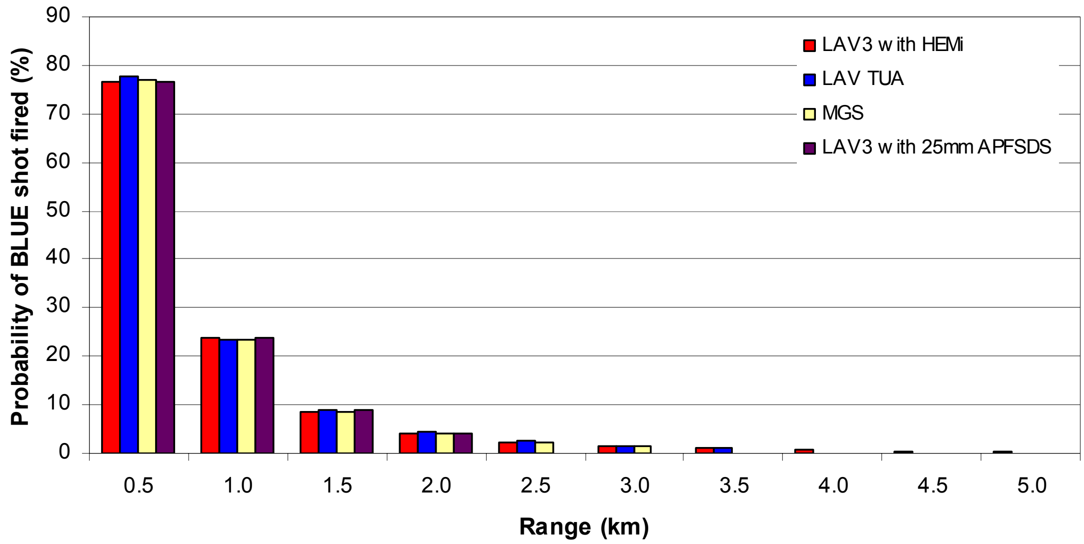

Figure C11. *BMP2 with AT-5, offensive scenario: probability of BLUE shot fired*

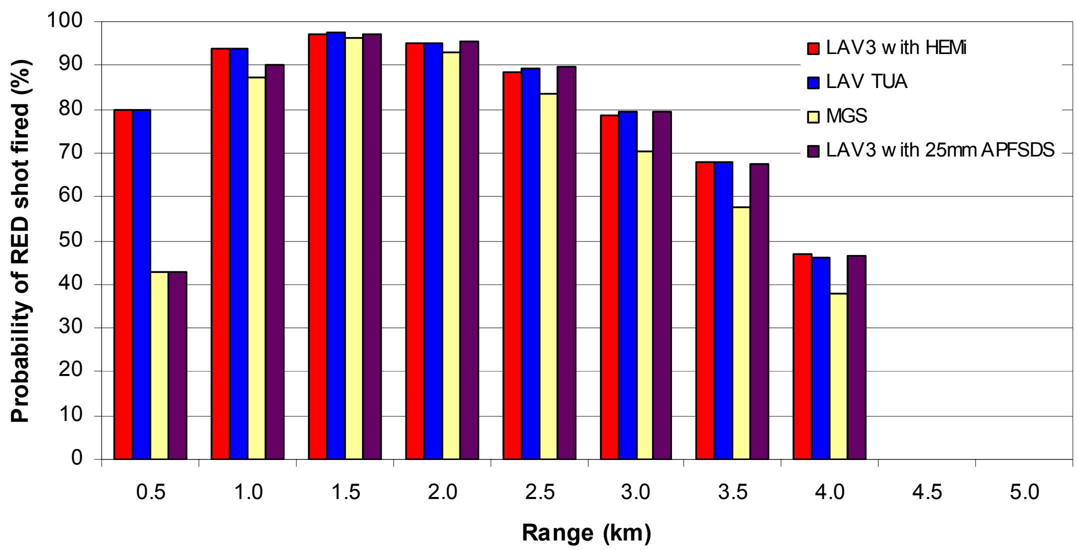

Figure C12. *BMP2 with AT-5, offensive scenario: probability of RED shot fired*

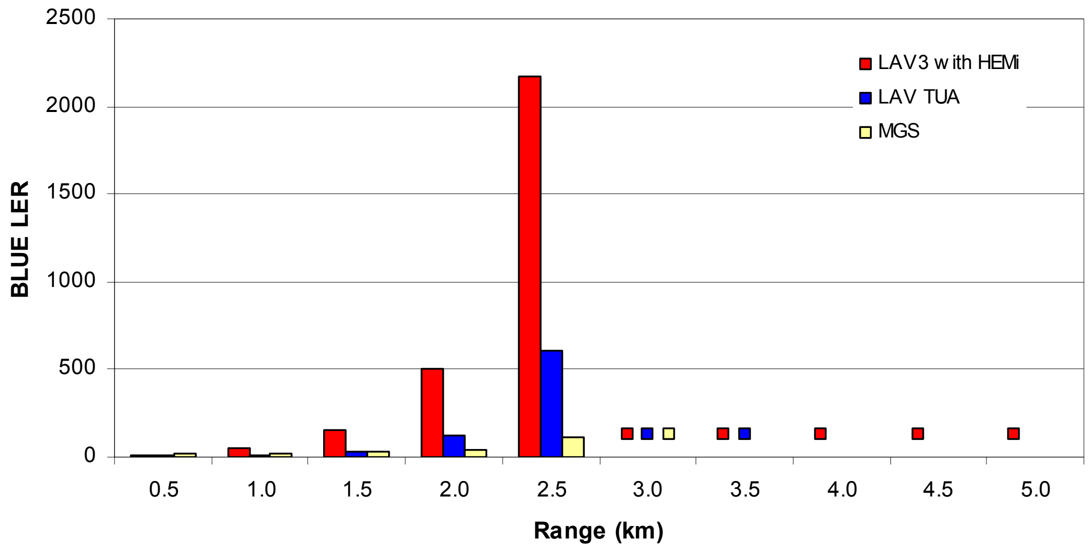

Figure C13. *T-80U with 125mm APFSDS, defensive scenario: LER*

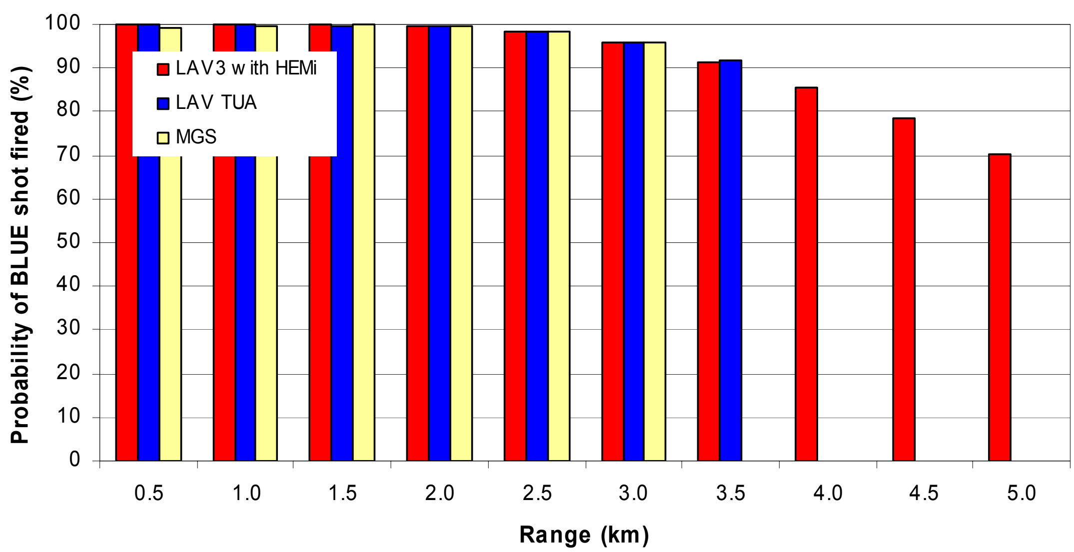

Figure C14. *T-80U with 125mm APFSDS, defensive scenario: probability of BLUE shot fired*

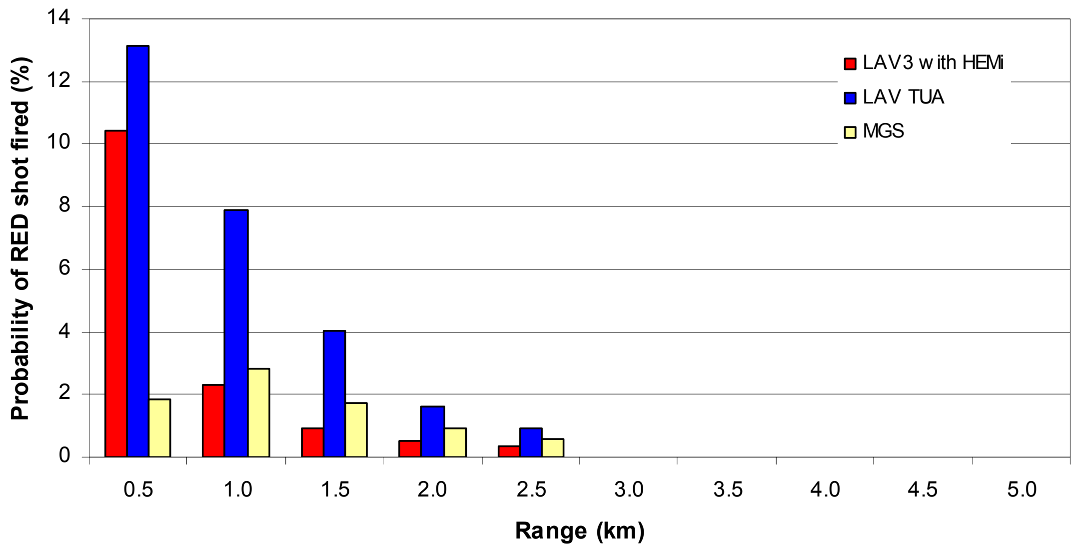

Figure C15. *T-80U with 125mm APFSDS, defensive scenario: probability of RED shot fired*

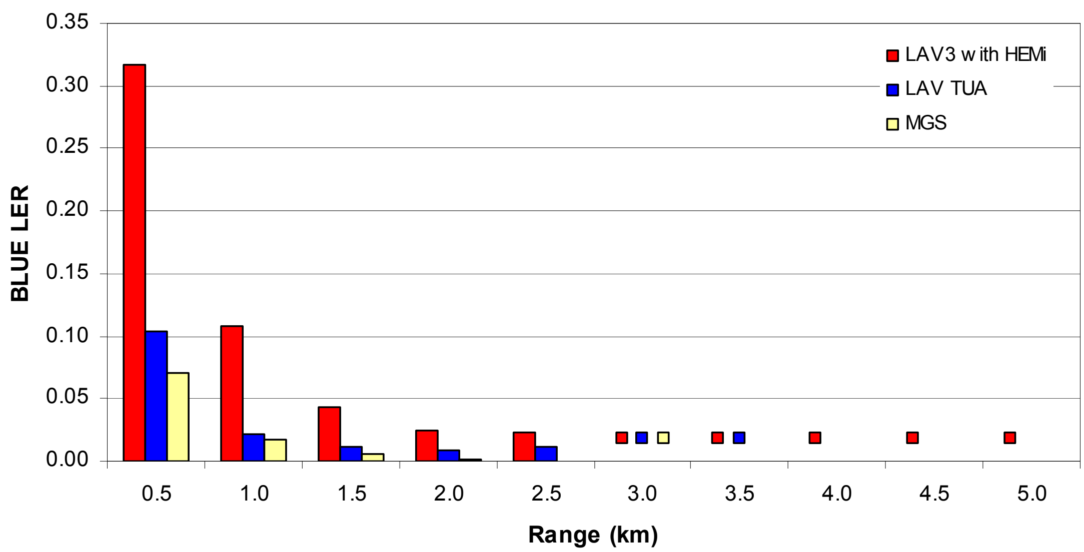

Figure C16. *T-80U with 125mm APFSDS, offensive scenario: LER*

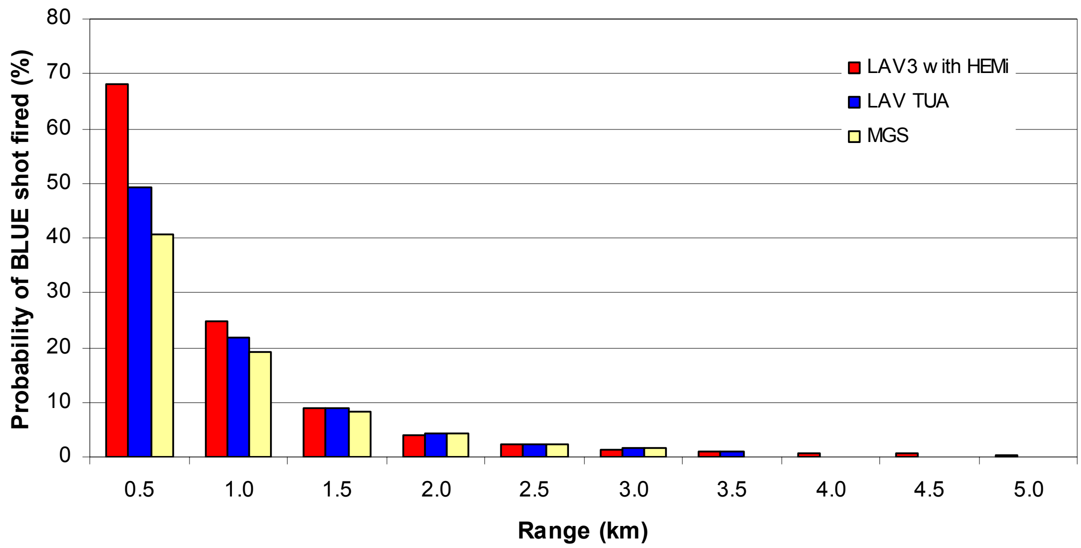

Figure C17. *T-80U with 125mm APFSDS, offensive scenario: probability of BLUE shot fired*

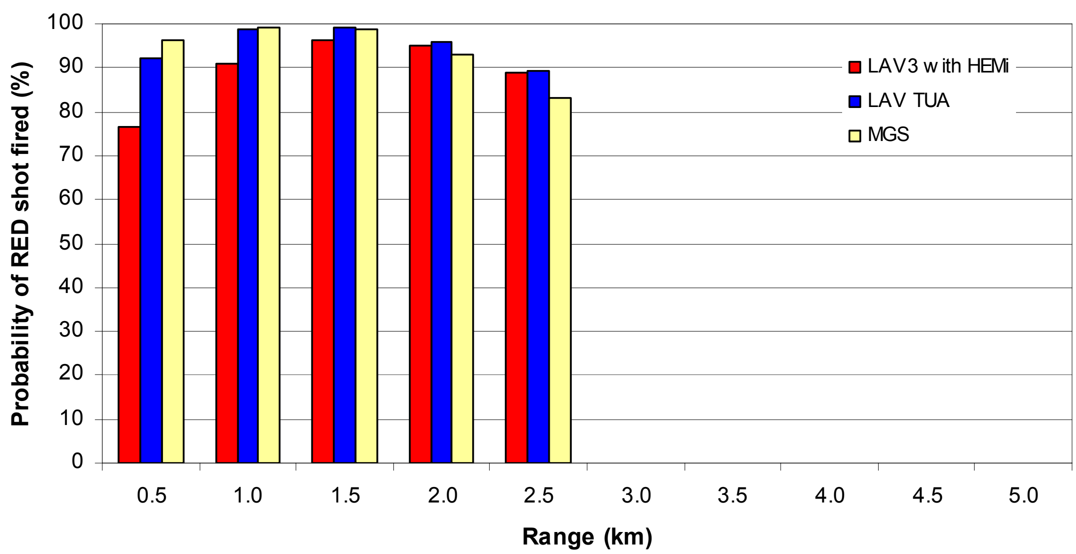

Figure C18. *T-80U with 125mm APFSDS, offensive scenario: probability of RED shot fired*

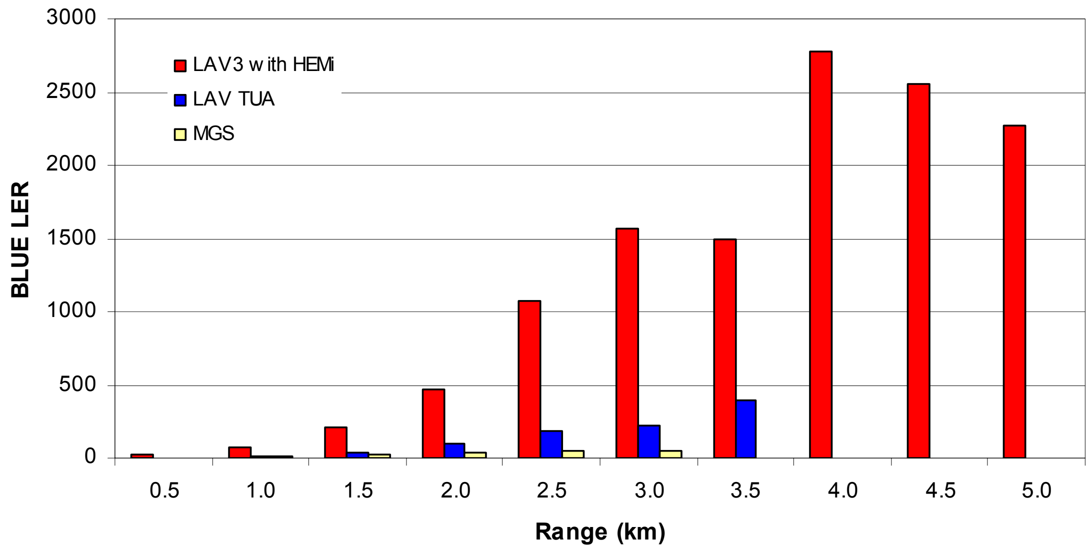

Figure C19. *T-80U with AT-11, defensive scenario: LER*

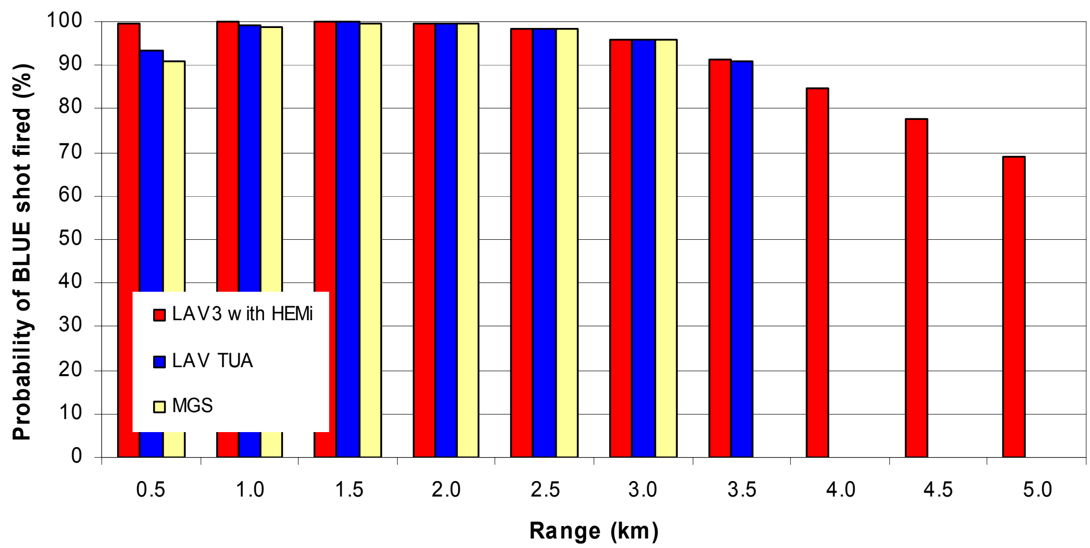

Figure C20. *T-80U with AT-11, defensive scenario: probability of BLUE shot fired*

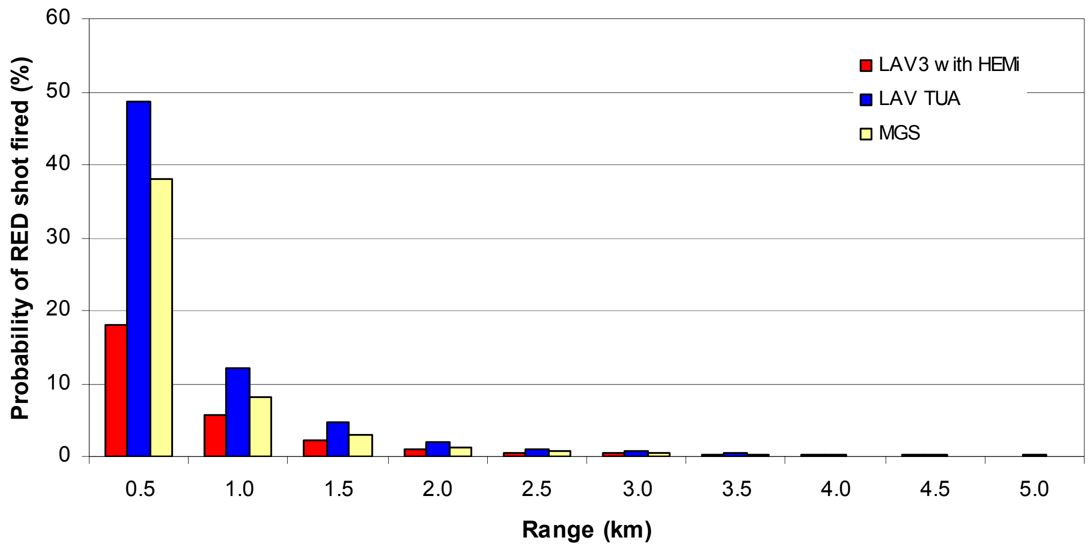

Figure C21. *T-80U with AT-11, defensive scenario: probability of RED shot fired*

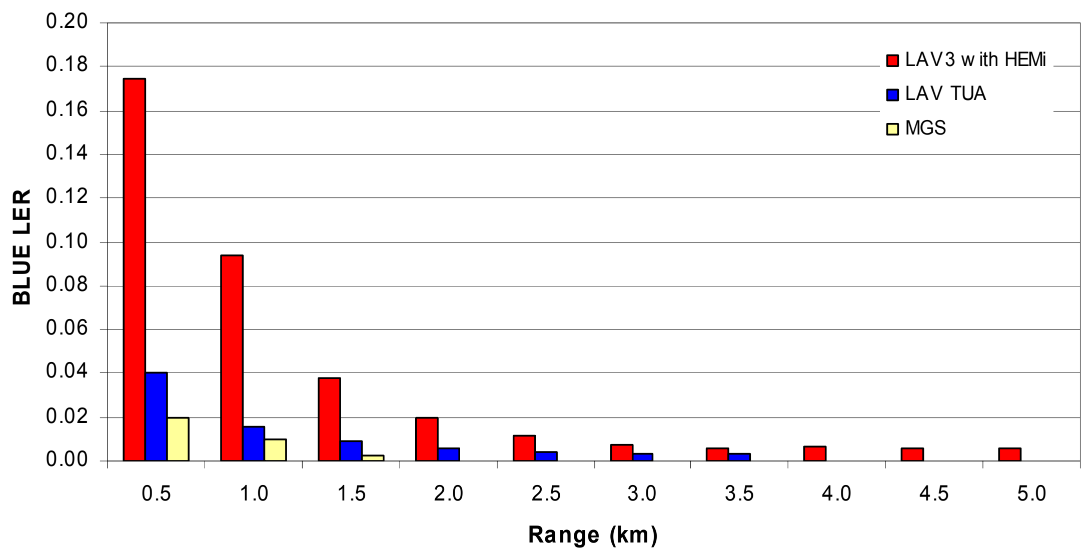

Figure C22. *T-80U with AT-11, offensive scenario: LER*

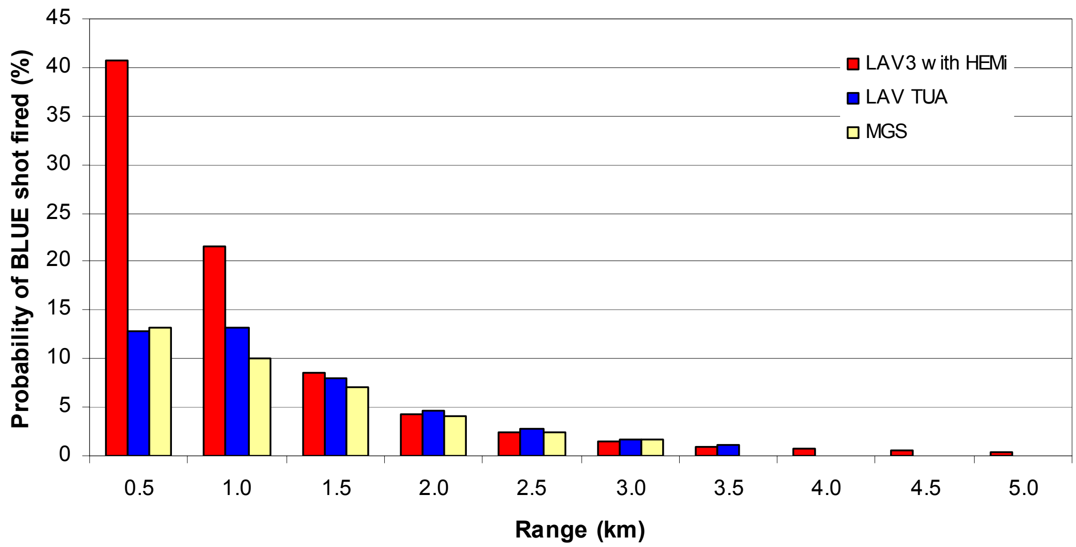

Figure C23. *T-80U with AT-11, offensive scenario: probability of BLUE shot fired*

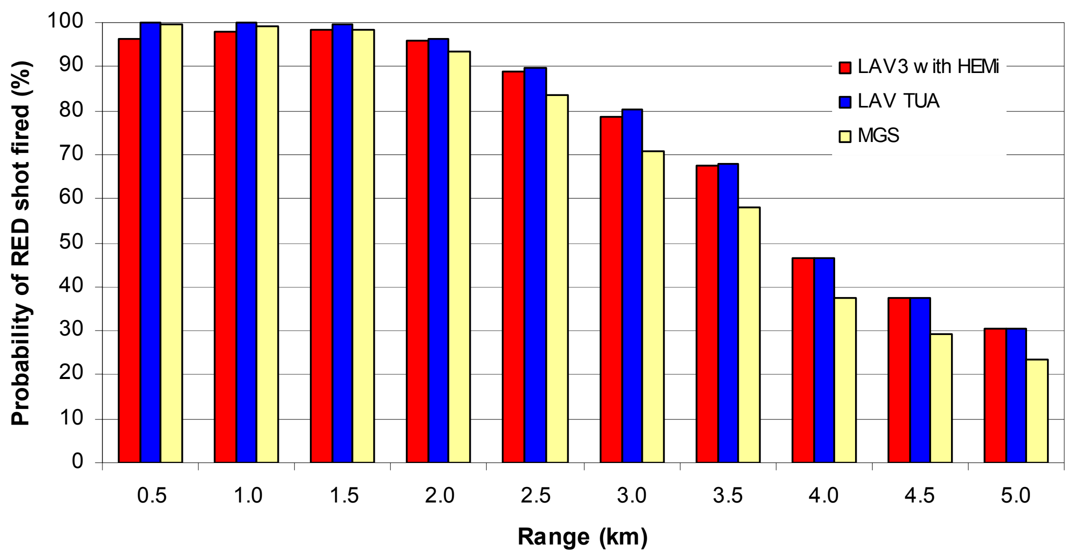

Figure C24. *T-80U with AT-11, offensive scenario: probability of RED shot fired*

Annex D

Table D1. *BMP2 with 30mm APDS-T, defensive scenario*

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS	LAV3 WITH 25MM APFSDS
LER				
0.5	6.4	6.1	9493.0	4754.0
1.0	39.4	29.0	91.6	139.2
1.5	226.0	74.6	172.7	195.6
2.0	inf	inf	inf	inf
2.5	inf	inf	inf	
3.0	inf	inf	inf	
3.5	inf	inf		
4.0	inf			
4.5	inf			
5.0	inf			
Probability of BLUE kill				
0.5	66.4	66.2	94.9	95.1
1.0	58.3	57.5	80.6	86.3
1.5	56.5	56.0	65.6	62.6
2.0	55.7	55.4	51.1	41.4
2.5	54.5	54.5	39.6	0.0
3.0	52.8	52.8	27.8	0.0
3.5	50.1	50.5	0.0	0.0
4.0	46.7	0.0	0.0	0.0
4.5	42.5	0.0	0.0	0.0
5.0	38.3	0.0	0.0	0.0
Probability of BLUE loss				
0.5	10.31	10.87	0.01	0.02
1.0	1.48	1.98	0.88	0.62
1.5	0.25	0.75	0.38	0.32
2.0	0.00	0.00	0.00	0.00
2.5	0.00	0.00	0.00	0.00
3.0	0.00	0.00	0.00	0.00
3.5	0.00	0.00	0.00	0.00
4.0	0.00	0.00	0.00	0.00
4.5	0.00	0.00	0.00	0.00
5.0	0.00	0.00	0.00	0.00

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS	LAV3 WITH 25MM APFSDS
Probability of BLUE shot fired				
0.5	100.0	100.0	100.0	100.0
1.0	100.0	100.0	100.0	100.0
1.5	99.9	99.9	100.0	100.0
2.0	99.5	99.7	99.6	99.7
2.5	97.9	98.3	98.3	0.0
3.0	95.0	95.4	95.4	0.0
3.5	90.1	91.1	0.0	0.0
4.0	84.1	0.0	0.0	0.0
4.5	76.6	0.0	0.0	0.0
5.0	68.8	0.0	0.0	0.0
Probability of RED shot fired				
0.5	10.33	10.89	0.02	0.02
1.0	2.13	2.71	1.37	0.88
1.5	0.81	2.24	1.08	1.05
2.0	0.00	0.00	0.00	0.00
2.5	0.00	0.00	0.00	0.00
3.0	0.00	0.00	0.00	0.00
3.5	0.00	0.00	0.00	0.00
4.0	0.00	0.00	0.00	0.00
4.5	0.00	0.00	0.00	0.00
5.0	0.00	0.00	0.00	0.00

Table D2. *BMP2 with 30mm APDS-T, offensive scenario*

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS	LAV3 WITH 25MM APFSDS
LER				
0.5	0.427	0.189	0.880	1.100
1.0	0.102	0.061	0.157	0.106
1.5	0.051	0.030	0.048	0.026
2.0	inf	inf	inf	inf
2.5	inf	inf	inf	
3.0	inf	inf	inf	
3.5	inf	inf		
4.0	inf			
4.5	inf			
5.0	inf			

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS	LAV3 WITH 25MM APFSDS
Probability of BLUE kill				
0.5	29.46	15.89	47.37	52.67
1.0	9.02	5.61	12.47	9.28
1.5	3.20	1.89	2.98	1.64
2.0	1.54	1.09	0.59	0.25
2.5	0.87	0.58	0.26	0.00
3.0	0.53	0.38	0.10	0.00
3.5	0.38	0.31	0.00	0.00
4.0	0.29	0.00	0.00	0.00
4.5	0.19	0.00	0.00	0.00
5.0	0.15	0.00	0.00	0.00
Probability of BLUE loss				
0.5	69.1	84.2	53.8	47.9
1.0	88.3	92.4	79.7	87.9
1.5	62.7	63.2	62.7	62.8
2.0	0.0	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0
3.0	0.0	0.0	0.0	0.0
3.5	0.0	0.0	0.0	0.0
4.0	0.0	0.0	0.0	0.0
4.5	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0
Probability of BLUE shot fired				
0.5	76.68	73.71	67.86	74.32
1.0	23.81	23.97	24.34	23.73
1.5	8.46	9.12	9.36	8.38
2.0	4.11	4.52	4.27	3.97
2.5	2.34	2.55	2.40	0.00
3.0	1.50	1.63	1.52	0.00
3.5	1.12	1.13	0.00	0.00
4.0	0.83	0.00	0.00	0.00
4.5	0.57	0.00	0.00	0.00
5.0	0.43	0.00	0.00	0.00
Probability of RED shot fired				
0.5	69.1	84.2	54.5	47.9
1.0	90.6	95.0	87.2	90.1
1.5	96.2	98.3	96.1	97.2
2.0	0.0	0.0	0.0	0.0
2.5	0.0	0.0	0.0	0.0
3.0	0.0	0.0	0.0	0.0
3.5	0.0	0.0	0.0	0.0
4.0	0.0	0.0	0.0	0.0
4.5	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0

Table D3. *BMP2 with AT-5, defensive scenario*

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS	LAV3 WITH 25MM APFSDS
LER				
0.5	24.5	23.7	9465.0	inf
1.0	97.7	77.4	215.4	275.2
1.5	220.0	206.3	250.0	230.5
2.0	708.1	610.2	318.6	262.9
2.5	1392.0	1082.6	303.1	0.0
3.0	2696.5	1312.5	273.4	0.0
3.5	2549.0	1251.5	0.0	0.0
4.0	4750.0	0.0	0.0	0.0
4.5	inf			
5.0	inf			
Probability of BLUE kill				
0.5	67.0	66.0	94.7	94.8
1.0	58.6	57.3	79.7	85.3
1.5	57.2	55.7	65.0	62.2
2.0	56.7	54.9	51.0	42.1
2.5	55.7	54.1	39.4	0.0
3.0	53.9	52.5	27.3	0.0
3.5	51.0	50.1	0.0	0.0
4.0	47.5	0.0	0.0	0.0
4.5	43.1	0.0	0.0	0.0
5.0	38.5	0.0	0.0	0.0
Probability of BLUE loss				
0.5	2.74	2.79	0.01	0.00
1.0	0.60	0.74	0.37	0.31
1.5	0.26	0.27	0.26	0.27
2.0	0.08	0.09	0.16	0.16
2.5	0.04	0.05	0.13	0.29
3.0	0.02	0.04	0.10	0.19
3.5	0.02	0.04	0.07	0.16
4.0	0.01	0.06	0.04	0.08
4.5	0.00	0.00	0.00	0.00
5.0	0.00	0.00	0.00	0.00
Probability of BLUE shot fired				
0.5	100.0	100.0	100.0	100.0
1.0	100.0	100.0	100.0	100.0
1.5	100.0	100.0	100.0	100.0
2.0	99.7	99.6	99.5	99.7
2.5	98.4	98.4	98.2	0.0
3.0	95.5	95.6	95.2	0.0
3.5	90.5	91.3	0.0	0.0
4.0	84.4	0.0	0.0	0.0
4.5	76.4	0.0	0.0	0.0
5.0	68.7	0.0	0.0	0.0

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS	LAV3 WITH 25MM APFSDS
Probability of RED shot fired				
0.5	9.86	10.03	0.01	0.00
1.0	2.34	2.43	1.29	0.96
1.5	0.87	1.03	0.84	1.09
2.0	0.33	0.55	0.51	0.75
2.5	0.18	0.53	0.32	0.87
3.0	0.11	0.51	0.26	0.56
3.5	0.09	0.37	0.26	0.38
4.0	0.04	0.17	0.15	0.17
4.5	0.00	0.00	0.00	0.00
5.0	0.00	0.00	0.00	0.00

Table D4. *BMP2 with AT-5, offensive scenario*

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS	LAV3 WITH 25MM APFSDS
LER				
0.5	0.594	0.313	1.758	1.818
1.0	0.150	0.091	0.208	0.159
1.5	0.054	0.033	0.042	0.029
2.0	0.025	0.016	0.007	0.004
2.5	0.016	0.009	0.003	
3.0	0.011	0.006	0.002	
3.5	0.008	0.006		
4.0	0.008			
4.5	inf			
5.0	inf			
Probability of BLUE kill				
0.5	30.06	19.12	54.20	54.26
1.0	8.92	5.76	11.99	9.30
1.5	3.34	2.09	2.65	1.76
2.0	1.52	0.96	0.40	0.26
2.5	0.87	0.50	0.14	0.00
3.0	0.55	0.33	0.08	0.00
3.5	0.35	0.26	0.00	0.00
4.0	0.23	0.00	0.00	0.00
4.5	0.19	0.00	0.00	0.00
5.0	0.12	0.00	0.00	0.00

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS	LAV3 WITH 25MM APFSDS
Probability of BLUE loss				
0.5	50.6	61.1	30.8	29.8
1.0	59.3	63.5	57.7	58.6
1.5	61.6	63.6	62.8	61.6
2.0	60.1	61.7	60.3	60.2
2.5	56.2	57.8	53.8	56.2
3.0	49.7	51.2	45.2	49.4
3.5	42.4	43.5	37.1	42.0
4.0	28.9	29.4	24.2	29.1
4.5	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0
Probability of BLUE shot fired				
0.5	77.89	77.59	77.16	76.46
1.0	23.54	23.44	23.58	23.84
1.5	8.91	9.10	8.70	8.83
2.0	4.16	4.47	4.06	4.25
2.5	2.27	2.48	2.38	0.00
3.0	1.48	1.44	1.66	0.00
3.5	0.97	0.99	0.00	0.00
4.0	0.63	0.00	0.00	0.00
4.5	0.49	0.00	0.00	0.00
5.0	0.35	0.00	0.00	0.00
Probability of RED shot fired				
0.5	68.2	79.8	42.9	42.9
1.0	90.6	94.0	87.3	90.1
1.5	96.0	97.3	96.4	97.1
2.0	94.5	95.2	93.1	95.6
2.5	88.9	89.4	83.5	89.6
3.0	79.0	79.4	70.5	79.3
3.5	67.8	68.0	57.6	67.7
4.0	46.4	46.1	37.8	46.4
4.5	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0

Table D5. *T-80U with 125mm APFSDS, defensive scenario*

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS
LER			
0.5	7.8	5.5	23.1
1.0	46.3	12.7	16.5
1.5	143.1	34.4	26.2
2.0	566.6	119.9	43.1
2.5	1115.4	606.7	118.0
3.0	inf	inf	inf
3.5	inf	inf	
4.0	inf		
4.5	inf		
5.0	inf		
Probability of BLUE kill			
0.5	67.0	65.1	34.6
1.0	58.9	55.2	25.7
1.5	57.3	55.1	18.1
2.0	56.7	55.1	12.1
2.5	55.8	54.6	9.4
3.0	54.4	53.1	6.7
3.5	52.1	50.8	0.0
4.0	48.2	0.0	0.0
4.5	44.3	0.0	0.0
5.0	39.7	0.0	0.0
Probability of BLUE loss			
0.5	8.54	11.78	1.50
1.0	1.27	4.35	1.56
1.5	0.40	1.60	0.69
2.0	0.10	0.46	0.28
2.5	0.05	0.09	0.08
3.0	0.00	0.00	0.00
3.5	0.00	0.00	0.00
4.0	0.00	0.00	0.00
4.5	0.00	0.00	0.00
5.0	0.00	0.00	0.00
Probability of BLUE shot fired			
0.5	100.0	99.9	99.4
1.0	100.0	99.8	99.6
1.5	100.0	99.8	99.8
2.0	99.7	99.5	99.5
2.5	98.4	98.4	98.5
3.0	95.9	95.9	95.9
3.5	91.9	91.6	0.0
4.0	85.3	0.0	0.0
4.5	78.0	0.0	0.0
5.0	70.1	0.0	0.0

Probability of RED shot fired			
0.5	9.64	13.16	1.84
1.0	2.32	7.91	2.83
1.5	0.98	4.02	1.72
2.0	0.53	1.63	0.91
2.5	0.37	0.95	0.55
3.0	0.00	0.00	0.00
3.5	0.00	0.00	0.00
4.0	0.00	0.00	0.00
4.5	0.00	0.00	0.00
5.0	0.00	0.00	0.00

Table D6. *T-80U with 125mm APFSDS, offensive scenario*

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS
LER			
0.5	0.567	0.103	0.070
1.0	0.163	0.022	0.017
1.5	0.067	0.011	0.005
2.0	0.041	0.009	0.001
2.5	0.037	0.011	0.000
3.0	inf	inf	inf
3.5	inf	inf	
4.0	inf		
4.5	inf		
5.0	inf		
Probability of BLUE kill			
0.5	34.81	9.06	4.92
1.0	12.70	1.93	1.31
1.5	4.69	0.83	0.34
2.0	2.26	0.51	0.06
2.5	1.33	0.40	0.01
3.0	0.90	0.57	0.01
3.5	0.61	0.39	0.00
4.0	0.39	0.00	0.00
4.5	0.32	0.00	0.00
5.0	0.20	0.00	0.00
Probability of BLUE loss			
0.5	61.5	87.9	70.1
1.0	77.8	88.6	77.3
1.5	70.2	73.0	67.3
2.0	54.7	55.5	52.0
2.5	36.3	37.0	35.6
3.0	0.0	0.0	0.0
3.5	0.0	0.0	0.0
4.0	0.0	0.0	0.0
4.5	0.0	0.0	0.0
5.0	0.0	0.0	0.0

Probability of BLUE shot fired			
0.5	67.93	49.26	40.72
1.0	24.38	21.76	19.11
1.5	8.83	9.02	8.36
2.0	4.03	4.34	4.28
2.5	2.37	2.47	2.42
3.0	1.67	1.61	1.61
3.5	1.17	1.10	0.00
4.0	0.78	0.00	0.00
4.5	0.63	0.00	0.00
5.0	0.38	0.00	0.00
Probability of RED shot fired			
0.5	64.5	92.3	96.5
1.0	86.7	98.7	99.2
1.5	94.8	99.1	98.9
2.0	93.9	95.9	93.2
2.5	87.6	89.1	83.2
3.0	0.0	0.0	0.0
3.5	0.0	0.0	0.0
4.0	0.0	0.0	0.0
4.5	0.0	0.0	0.0
5.0	0.0	0.0	0.0

Table D7. *T-80U with AT-11, defensive scenario*

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS
LER			
0.5	17.2	4.3	3.4
1.0	67.6	14.1	14.9
1.5	209.6	37.6	27.0
2.0	700.9	94.1	40.7
2.5	692.3	186.7	45.0
3.0	1345.3	227.6	51.5
3.5	1274.8	400.2	
4.0	2374.0		
4.5	2177.0		
5.0	1970.0		
Probability of BLUE kill			
0.5	66.7	57.6	32.5
1.0	58.1	56.0	26.2
1.5	56.6	56.4	18.1
2.0	56.1	56.4	12.2
2.5	55.4	56.0	9.5
3.0	53.8	54.6	6.7
3.5	51.0	52.0	0.0
4.0	47.5	0.0	0.0
4.5	43.5	0.0	0.0
5.0	39.4	0.0	0.0

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS
Probability of BLUE loss			
0.5	3.87	13.41	9.61
1.0	0.86	3.96	1.75
1.5	0.27	1.50	0.67
2.0	0.08	0.60	0.30
2.5	0.08	0.30	0.21
3.0	0.04	0.24	0.13
3.5	0.04	0.13	0.13
4.0	0.02	0.06	0.04
4.5	0.02	0.04	0.02
5.0	0.02	0.03	0.02
Probability of BLUE shot fired			
0.5	99.8	93.6	91.1
1.0	99.9	99.4	98.8
1.5	99.9	99.8	99.6
2.0	99.6	99.5	99.5
2.5	98.4	98.5	98.6
3.0	95.8	95.8	95.8
3.5	90.8	91.1	0.0
4.0	84.4	0.0	0.0
4.5	77.3	0.0	0.0
5.0	69.8	0.0	0.0
Probability of RED shot fired			
0.5	18.88	48.60	38.13
1.0	5.71	12.15	8.26
1.5	2.60	4.75	2.93
2.0	1.25	2.04	1.14
2.5	0.76	1.10	0.71
3.0	0.48	0.76	0.43
3.5	0.32	0.48	0.33
4.0	0.16	0.22	0.12
4.5	0.13	0.17	0.10
5.0	0.11	0.13	0.06

Table D8. *T-80U with AT-11, offensive scenario*

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS
LER			
0.5	0.286	0.040	0.020
1.0	0.154	0.016	0.010
1.5	0.063	0.009	0.003
2.0	0.032	0.006	0.000
2.5	0.020	0.005	0.000
3.0	0.013	0.003	0.000
3.5	0.010	0.003	
4.0	0.010		
4.5	0.007		
5.0	0.008		
Probability of BLUE kill			
0.5	19.24	3.30	1.58
1.0	10.63	1.25	0.73
1.5	4.60	0.68	0.21
2.0	2.28	0.42	0.00
2.5	1.33	0.31	0.00
3.0	0.80	0.19	0.00
3.5	0.50	0.16	0.00
4.0	0.37	0.00	0.00
4.5	0.21	0.00	0.00
5.0	0.19	0.00	0.00
Probability of BLUE loss			
0.5	67.3	82.6	79.2
1.0	69.2	78.9	74.7
1.5	72.8	77.3	73.9
2.0	71.9	74.7	70.4
2.5	67.3	69.5	63.4
3.0	60.0	62.3	53.9
3.5	51.5	52.7	44.1
4.0	35.8	36.2	28.4
4.5	28.3	28.9	22.3
5.0	22.6	23.8	18.0

RANGE (KM)	LAV3 WITH HEMI	LAV TUA	MGS
Probability of BLUE shot fired			
0.5	40.57	12.87	13.28
1.0	22.16	13.15	10.11
1.5	8.92	7.92	7.10
2.0	4.14	4.56	4.17
2.5	2.38	2.70	2.40
3.0	1.50	1.65	1.60
3.5	1.00	1.10	0.00
4.0	0.78	0.00	0.00
4.5	0.46	0.00	0.00
5.0	0.36	0.00	0.00
Probability of RED shot fired			
0.5	93.9	100.0	99.8
1.0	95.9	99.9	99.4
1.5	97.5	99.5	98.4
2.0	94.9	96.5	93.2
2.5	88.6	89.8	83.5
3.0	78.8	80.2	71.0
3.5	67.4	67.9	57.9
4.0	46.7	46.7	37.3
4.5	37.1	37.4	29.3
5.0	29.8	30.5	23.6

List of abbreviations and acronyms

APDS-T	Armour-Piercing Discarding Sabot - Tracer
APFSDS	Armour-Piercing Fin-Stabilized Discarding Sabot
BMP2/30	BMP2 with 30 mm APDS-T
BMP2/AT5	BMP2 with AT-5
DLSE	Directorate of Land Synthetic Environments
DRDC	Defence Research and Development Canada
FLIR	Forward-Looking Infra-Red
FOV	field of view
HEMi	High Energy Missile
LAV	Light Armoured Vehicle
LAV3/25	LAV3 with 25 mm APFSDS
LAV3/HEMi	LAV3 with HEMi
LER	Loss Exchange Ratio
MBT	Main Battle Tank
MGS	Mobile Gun System
NFOV	Narrow Field of View
OR	Operational Research
P_{hit}	probability of hit
$P_{kill/hit}$	probability of kill given a hit
T80U/125	T-80U with 125 mm APFSDS
T80U/AT11	T-80U with AT-11
TDP	Technology Demonstration Project
TOW	Tube-launched, Optically-tracked, Wire-guided missile

TTPs	Tactics, Techniques, and Procedures
TUA	TOW Under Armour
WES	Weapons Effects Simulation
WFOV	Wide Field of View

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This study uses a simple spreadsheet model to simulate a one-on-one engagement between two combat vehicles with the objective of comparing the performance of the High Energy Missile (HEMi) mounted on a Light Armoured Vehicle (LAV3) with that of the LAV TOW Under Armour (LAV TUA), the Mobile Gun System, and the 25 mm APFSDS on a LAV3. These BLUE systems were placed in conflict with a variety of RED threats, both guided and unguided.

The results suggest that in long-range engagements or in engagements with a T-80U at any range, the LAV3 carrying the HEMi is the superior system. Both the MGS and the LAV3 with a 25 mm APFSDS are better suited to shorter-range engagements against a BMP2.

Dans la présente étude, un modèle simple de chiffrier électronique a été utilisé pour simuler un engagement un-contre-un entre deux véhicules avec pour objectif de comparer la performance du missile à haute énergie (HEMi) monté sur véhicule blindé léger (VBL III) à celles du VBL TSB (TOW sous blindage), du système de canon mobile (Mobile Gun System – MGS) et du canon de 25 mm avec projectile de type fléchette monté sur VBL III. Ces systèmes BLEU ont été placés en conflit avec diverses menaces ROUGE, tant guidées que non-guidées.

Les résultats semblent indiquer que, dans les engagements à longue portée et dans tous les engagements contre le T-80U, indépendamment de la portée, le VBL III armé du système HEMi est supérieur. Le système de canon mobile et le VBL III armé du canon de 25 mm avec projectile de type fléchette sont mieux adaptés pour les engagements à courte portée contre le BMP2.

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High Energy Missile

Anti-Tank Guided Missile

Light Armoured Vehicle

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